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THE JOURNAL OF WILDLIFE MANAGEMENT

APRIL - 1953
Vol. 17 No. 2

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The Journal of Wildlife Management is printed by the Cayuga Press, Inc., and published by The Wildlife Society in January, April, July and October, at 113 East Green St., Ithaca, N. Y. Subscription $5.00 per year and current numbers $1.25. Society members cover subscription in annual dues. Back issues are available; volumes 1 through 8, and 13 at $8; 9 through 12, and others since 1949 at $6 per volume, $1.50 per issue.

Manuscripts for publication, books and papers for review, news notes and correspondence concerning them should be sent to the *Editor*, Oliver H. Hewitt, Department of Conservation, Cornell University, Ithaca, N. Y.

Dues, subscriptions, changes of address, requests for missing numbers, applications for membership, and other correspondence should be sent to the *Executive Secretary*, G. A. Petrides, Michigan State College, Dept. Fish and Wildlife, East Lansing, Mich.

The Society is not responsible for supplying missing issues unless the Secretary is notified within 60 days of the date of publication.

Entered as Second Class Matter, at the Post Office at Ithaca, New York, June 18, 1951, under the Act of March 3, 1879.

Articles in this Journal are indexed in the Agricultural Index, available in many libraries.

THE JOURNAL OF WILDLIFE MANAGEMENT

VOLUME 17 APRIL, 1953 NUMBER 2

DEER AND SHEEP COMPETITION IN UTAH [1]

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INTRODUCTION

The demands placed on a limited range resource by both stockmen and sportsmen have brought about much controversy regarding competition between big game and livestock. This question of competition assumes its greatest importance where large numbers of game occur on a private range whose owner has a business investment and livelihood at stake, and on valuable watersheds where public interests may require adjustments in numbers of grazing animals. A knowledge of the forage habits of the grazing animals is essential in the multiple-use management of such ranges.

The object of this study was to determine the seasonal food habit relationships of deer and sheep on the range including both forage preferences and the extent of overlap in areas grazed by each.

Competition between deer and sheep connotes a conflict for the same object and involves two ramifications that need to be defined:

(1) If the supply of a forage species used in common is inadequate for the requirements of both animals there will be a conflict for that species. Actually, the conflict does not begin until the utilization of a species reaches the point that is considered "proper," because up to that point there is available forage for either or both to take as they choose. For example, assume that clover, which is a favorite food of both deer and sheep, is considered properly utilized when 60 percent of the annual growth has been removed. If the combined deer and sheep use is 50 percent there is no conflict as yet because there is still 10 percent of the current growth that can be utilized before the proper level of use is exceeded. On the other hand, if the combined use exceeds 60 percent it is obvious that this amount is not sufficient to satisfy the combined requirements of the animals and conflict becomes active. This kind of competition will be referred to hereafter as "forage" competition. It might be well to mention that because ranges are not grazed uniformly the key areas (important feed-grounds for both deer and sheep) of a grazing unit will be the first to show forage competition and that conflict may diminish, as the distance from the key areas increases, until a point is reached where there is none.

(2) When deer and sheep choose the

[1] This study is part of a cooperative project being conducted by the Utah State Fish and Game Commission, U. S. Fish and Wildlife Service, Utah State Agricultural College, and U. S. Forest Service.

same forage species they may be in competition with each other even though the forage supply is adequate to satisfy their combined requirements and there is no conflict produced because proper use has not been exceeded for any species. The fact that they choose the same species makes it evident that if part of the deer population was removed sheep numbers could be increased and vice versa. Hence, the administrator is constantly faced with the problem of making the optimum allocation of grazing capacity with due regard for the physical, economic, and social factors involved. Competition in this sense is not competition for forage but for land use and will be so designated in subsequent discussion.

It should be pointed out that when two species of grazing animals have entirely different forage preferences it is possible to have an overgrazed range without having competition between them. In a situation of this kind the competition would be between individuals within a species.

The area studied was the Monroe Mountain sheep allotment on the Fishlake National Forest in central Utah. Supplementary data from a comparable area on the Manti-LaSal National Forest near Ephraim, Utah have also been included. The Monroe Mountain sheep allotment is typical of much deer-sheep range in Utah. Elevations vary from 6,500 to 11,000 feet. The foothills, covered by juniper and sagebrush, are winter and early spring deer range and spring sheep range. The higher country where both deer and sheep summer is covered partly by aspen, conifers, and mixtures of the two interspersed with shrub types and partly by shrub types interspersed with small patches of conifers. The intermediate area is mountain brush type which is used by deer in spring and fall and by sheep, in alternate years, in early summer and early fall.

This range has been overgrazed in the past by both deer and sheep. The lower winter deer range (lower juniper-sage type) especially is in a depleted condition and grasses, forbs, and more palatable browse species are scarce. The spring deer range (upper juniper-sage and lower mountain shrub) is also depleted from past overuse but is in much better condition than the lower winter range. The summer range, although showing many sore spots from past overuse, has a good mixture of palatable plants over much of the area. Material reductions in both deer and sheep numbers have been made in recent years. Sheep graze only once over all accessible range using alternate routes of grazing every other year. Open herding and the bedding-out of sheep are practiced. Some parts of both summer and winter range show heavy current use but on the areas of intensive study the palatable forage plants were not severely utilized and the food habit data represent natural preferences of deer and sheep on this type of range.

REVIEW OF LITERATURE

Shantz (1938) pointed out that where game and livestock use the same forage species, whether by choice or necessity, conflict is often alleviated by the fact that game use areas inaccessible to livestock, although this difference in areal use is much greater with cattle than with sheep. Stoddart and Rasmussen (1945 a and b) presented a method of calculating direct competition by mak-

ing use of the differences in both area used and food habits. They, and Haskell (1946), concluded that conflict between sheep and deer may be severe on overgrazed range, but that under proper stocking sheep will not eat appreciable amounts of the plants which make up half of the deer's diet. On the other hand, Johnson (1944) felt that where range conditions were favorable enough so that normal food preferences could be enjoyed, the feeding habits of sheep and deer were quite similar. Dixon (1928) found that over 60 percent of the plants eaten by deer in the summer were taken regularly by sheep and in his intensive report on the food habits of mule deer in California (1934), he cites a study by A. W. Sampson in which it was determined that 82 percent of the food plants eaten by deer are palatable to sheep. The viewpoint that competition, brought about by similarity in food habits, does exist has also been expressed by Mann (1933), Boone (1938), and Schwan (1945). Fischer *et al.*, (1944) reported similar diets for sheep and deer in the spring, but minimized conflict because of the abundance of the species used by both. In a study involving the use of movable paddocks for determining forage preferences, Smith and Gaufin (1950) found that several species were used heavily by both deer and sheep.

METHODS

Weight and utilization of herbage were estimated by species on permanent circular plots of either 48 or 96 square feet, spaced at regular intervals along lines which were randomly spaced within each vegetal type. The small plots were used where the vegetation was dense, the large ones where it was sparse. The number of plots established at each location ranged from 30 to more than 100 according to the standard for sampling the total vegetation within a 10 percent error in the various types. Sheep use was separated from deer use by making one observation just prior to the time sheep entered an area and another immediately after they left. The elapsed time, which was usually 1 to 3 days, was negligible from the standpoint of forage growth.

In order to determine the proportion of the range used by each class of animal, parallel transects spaced at an interval of one-half mile were run across the sheep grazing allotment from one boundary to the other. On each of these transects, a temporary plot was established every 4 chains on which was recorded utilization by species, deer sign, and sheep sign. These data were supplemented by information secured from the herder and sheep owner relative to sheep and deer use and by observation of the authors over all parts of the study area at different seasons.

Weights were determined by the weight estimate method described by Pechanec and Pickford (1937a). The method used to determine utilization was the ocular-estimate-by-plot supplemented by a modified volume-by-weight method (Pechanec and Pickford, 1937b).

The word "diet" is used in the following discussion to represent the total forage consumed by each class of animal as computed from the observations made. Obviously, the actual deer or sheep diet may have included one or more species that did not occur within the immediate area of observation. However, it is believed that the sample

taken in each vegetal type was large enough to preclude the possibility of missing any species that made up an appreciable part of the total volume.

SUMMER COMPETITION

The grazing area that receives the longest period of use by deer and sheep at the same time and therefore represents the zone in which the most conflict is likely to occur on the study unit, is the summer range.

Observations on summer feeding habits of deer and sheep were made in July and August during the period 1947-50 inclusive. Six vegetal types were studied which represent the bulk of summer sheep range in the vicinity of the investigation. These types are the spruce-fir, aspen, currant-snowberry, sage-chokecherry, sage-snowberry, and sage-grass. The aspen type was observed at three areas and the currant-snowberry at two; all the others represent data gathered from single areas. The sage-snowberry and sage-grass types were studied only one year whereas each of the other types was studied two years. In all cases where studies in a type were made at more than one location or in more than one year, or both, all data for the type were consolidated. The principal species in each type are as follows:

Spruce-Fir, Elevation 9,700 ft.—Engelmann spruce (*Picea engelmanni*), white fir (*Abies concolor*), aspen (*Populus tremuloides*), snowberry (*Symphoricarpos* spp.) creeping mahonia (*Mahonia repens*), gooseberry currant (*Ribes montigenum*), clover (*Trifolium* sp.), heartleaf arnica (*Arnica cordifolia*), sedge (*Carex* sp.), nodding brome (*Bromus anomalus*).

Aspen, Elevation 9,600 ft.—Aspen, big sagebrush (*Artemisia tridentata*), silver sagebrush (*A. cana*), creeping mahonia, snowberry, clover, dandelion (*Taraxacum officinale*), heartleaf arnica, yarrow (*Achillea lanulosa*), red fescue (*Festuca rubra*), sedge, bluegrass (*Poa* sp.).

Currant-Snowberry, Elevation 9,800 ft.—Gooseberry currant, snowberry, rabbitbrush (*Chrysothamnus* sp.), tall bluebells (*Mertensia leonardi*), pentstemon (*Pentstemon* sp.), dandelion, Letterman needlegrass (*Stipa lettermani*), mountain brome (*Bromus carinatus*), bluestem wheatgrass (*Agropyron smithii*).

Sage-Chokecherry, Elevation 9,000 ft.—Big sagebrush, chokecherry (*Prunus virginiana*), snowberry, penstemon, fleabane (*Erigeron* sp.) dandelion, Letterman needlegrass, mutton bluegrass (*Poa fendleriana*).

Sage-Snowberry, Elevation 10,000 ft.—Big sagebrush, snowberry, gooseberry currant, dandelion, lupine (*Lupinus alpestris*), mutton bluegrass, Letterman needlegrass, slender wheatgrass (*Agropyron trachycaulum*).

Sage-Grass, Elevation 9,600 ft.—Silver sagebrush, dandelion, bistort (*Polygonum bistortoides*), cinquefoil (*Potentilla filipes*), red fescue, sheep fescue (*Festuca ovina*), sedge, Letterman needlegrass.

There is great variation between types in the vegetal composition of the summer range, but it is primarily a browse range with browse species supplying slightly more than half of the available herbage (Table 1). Forbs and grasses, in about equal amounts, supply the remainder.

Utilization was recorded on 96 species of plants of which 18 were browse, 55

TABLE 1.—VEGETAL COMPOSITION OF SPRING AND SUMMER RANGES, 1947–50

Season and type	Total available herbage		
	Browse	Forbs	Grasses & sedges
	Percent	*Percent*	*Percent*
Summer			
Spruce-fir	50	41	9
Aspen	31	32	37
Currant-snowberry	37	24	39
Sage-chokecherry	72	19	9
Sage-snowberry	87	5	8
Sage-grass	45	14	41
Average all types	(54)	(22)	(24)
Spring			
Sage-oak	78	7	15
Pinyon-juniper	91	2	7
Average all types	(84)	(5)	(11)

were forbs, and 23 were grasses and sedges. Table 2 shows the number of species in each vegetal class that were used by deer and by sheep. It is of interest to note that deer were apparently more selective than sheep in their choice of browse and grass species whereas both animals exhibited a wide choice of forbs. The difference in choice of species is manifest in the grasses where sheep selected nearly twice as many as deer.

Although a large number of species were used by each class of animal, the major portions of the diets in all vegetal types were made up of the 22 species listed in Table 3. The importance of a few species in the diets is illustrated in this table which shows that 8 species or fewer account for two-thirds or more of the diets in each type. Furthermore the similarity in choice of foods by deer and sheep is evident in the spruce-fir, currant-snowberry, and sage-chokecherry types where the same 8 species composed two-thirds or more of each diet. This similarity is less pronounced in the other three types yet more than half of each diet in the aspen type was made up of the same 8 species. In the sage-snowberry type a large part of the sheep diet was made up of grass and browse species which were not used by deer; likewise most of the sheep diet in the sage-grass type consisted of grasses which deer did not use.

The ten species most prominent in each diet, on the basis of total summer utilization in all types, are presented in Table 4. It is again apparent, from this table, that deer and sheep diets were very much alike because 6 of the 10 species most prominent in each diet were also prominent in both diets. These species are aspen, chokecherry, snowberry, clover, dandelion, and Letterman needlegrass. Inasmuch as none of these species were utilized excessively, their selection was not unduly influenced by their scarcity.

In addition to the comparison of deer and sheep diets on the basis of species it is of interest to compare them on the basis of forage classes as indicated in

TABLE 2.—DEER AND SHEEP SUMMER AND SPRING UTILIZATION BY NUMBER OF SPECIES IN EACH VEGETAL CLASS, 1947–50

	Browse		Forbs		Grasses and sedges	
	Summer	Spring	Summer	Spring	Summer	Spring
No. species used by deer	12	10	51	10	12	10
No. species used by sheep	18	14	53	24	23	11
Total No. species used	18	15	55	24	23	11

TABLE 3.—DEER AND SHEEP DIETS ON SUMMER RANGE, 1947–50 (Diet figures are percent of total forage consumed by each class of animal as determined by weight and utilization estimates)

Species	Vegetal Type											
	Spruce-fir		Aspen		Currant-Snowberry		Sage-Chokecherry		Sage-Snowberry		Sage-Grass	
	D	S	D	S	D	S	D	S	D	S	D	S
Artemisia cana	–	–	5	4	–	–	–	–	–	–	0	T*
Chrysothamnus lanceolatus	–	–	–	–	2	6	0	6	0	4	–	–
Populus tremuloides	18	33	14	9	1	T	1	1	–	–	–	–
Prunus virginiana	–	–	2	T	–	–	18	32	–	–	–	–
Symphoricarpos oreophilus	T	T	1	2	30	9	2	9	0	25	–	–
Achillea lanulosa	1	T	2	1	4	1	–	–	–	–	0	T
Aster spp.	2	4	1	1	–	–	1	2	9	2	–	–
Castilleja linariaefolia	16	1	5	T	–	–	6	1	5	1	–	–
Erigeron spp.	–	–	–	–	–	–	1	6	–	–	12	T
Lupinus alpestris	–	–	1	4	–	–	23	6	69	3	–	–
Mertensia leonardi	T	11	0	6	11	34	0	1	–	–	–	–
Pentstemon watsoni	2	3	6	1	13	3	12	2	2	2	0	T
Phacelia sp.	–	–	T	T	–	–	–	–	4	3	–	–
Potentilla filipes	T	T	1	T	0	2	–	–	–	–	2	5
Taraxacum officinale	–	–	4	6	6	5	6	2	–	–	49	29
Trifolium sp.	46	15	43	19	–	–	–	–	–	–	8	T
Agropyron trachycaulum	–	–	2	3	4	1	–	–	0	3	0	2
Bromus carinatus	–	–	0	3	1	11	–	–	–	–	–	–
Carex spp.	2	8	T	7	0	1	T	2	–	–	0	8
Festuca rubra	–	–	0	11	–	–	–	–	–	–	0	15
Poa fendleriana	1	1	1	7	1	3	4	10	0	27	0	15
Stipa lettermani	–	–	–	–	T	8	6	7	8	9	0	6
Total	88	76	88	84	73	84	80	87	97	79	71	80

* Less than 1 percent.

Figure 1. It is evident from this figure that forbs played the most prominent part in the summer deer diet in all types but one. Forbs were also prominent in the summer sheep diet in most types and in total summer use in all types combined. Although there was considerable variation in utilization of browse by deer and sheep within types the total summer browse use by sheep was only slightly more than that by deer. The greatest difference between the two diets was found in the use of grass. In every type the volume of grass in the summer sheep diet was much larger than in the deer diet and was 5 times as large for the summer as a whole.

It is obvious from the above discussions of Tables 3 and 4 and Figure 1 that the summer diets of deer and sheep were similar, particularly with respect to use of forbs and browse. This similarity of diet indicates that there was considerable land-use competition between deer and sheep on the summer range of the study area. On the other hand, since the data do not show a conflict for any species, as evidenced by excessive utilization, there was no apparent forage competition.

Because the forage preferences of the two animals differ between vegetal types the nature and extent of competition may also vary with type. For instance, the probability of competition

TABLE 4.—SPECIES MOST PROMINENT IN DEER AND SHEEP TOTAL DIETS ON SUMMER AND SPRING RANGE, 1947–50

Species	Percent of diet		Percent total utilization
	Deer	Sheep	
Summer Range			
Populus tremuloides	6	7	29
Prunus virginiana	3	5	42
Symphoricarpos oreophilus	5	7	15
Aster spp.	2	–	52
Castilleja linariaefolia	5	–	44
Lupinus alpestris	15	–	59
Mertensia leonardi	–	9	72
Pentstemon watsoni	6	–	35
Taraxacum officinale	11	7	38
Trifolium sp.	16	6	51
Carex spp.	–	4	44
Festuca rubra	–	4	21
Poa fendleriana	–	10	51
Stipa lettermani	2	5	30
Totals	71	64	
Spring Range			
Artemisia tridentata	4	–	Trace
Cercocarpus montanus	13	26	33
Chrysothamnus lanceolatus	–	10	36
Agropyron cristatum	–	5	50
Agropyron spicatum	7	4	14
Poa fendleriana	43	25	59
Poa pratensis	4	3	85
Sitanion hystrix	4	–	4
[1] Totals	75	73	

in the sage-snowberry type where forage preferences were different was much less than it was in the spruce-fir type where they were similar.

Although deer and sheep graze the same general areas deer will frequent terrain not used by sheep because of insufficient or undesirable forage or difficult access. This difference in areal use will vary with each locality and cannot be expressed in general terms. It is important, however, because if it is large it will have a definite influence on degree of competition. An effort was made by the writers to determine the difference in areal use by deer and sheep on the 8,400-acre summer grazing allotment which served as the base for most of this study. The area was traversed in the manner described under *Methods*. This survey revealed that deer used the entire allotment with the exception of inaccessible rocky cliffs and ledges, whereas sheep grazed approximately 6,600 acres or 80 percent of the area. Thus forage was provided for the exclusive use of deer on 20 percent of the allotment and the extent of competition was thereby reduced. It should be pointed out, however, that the greatest deer utilization occurred on the area used in common with sheep.

Figure 2 shows the overlap in deer and sheep use. With few exceptions areas unused or lightly used by sheep were lightly used by deer and generally the areas more closely used by sheep were the areas of heaviest deer concentration. A few areas having good forage but inaccessible to sheep showed relatively high deer use. Some of the more open dry slopes and flats were used lightly by deer and more intensively by sheep.

SPRING COMPETITION

Ordinarily the foothill areas which comprise spring range are not used by deer and sheep at the same time. Deer use them in winter and also in early spring while the vegetation is in the active growing stage and then move on up the mountains in their annual spring migration. By the time sheep reach the spring range the greater part of the vegetation has either completed its growth or at least made some regrowth following utilization by deer. The probability of competition is therefore less than it is on summer range.

Observations were made on spring range in June and early July of 1947,

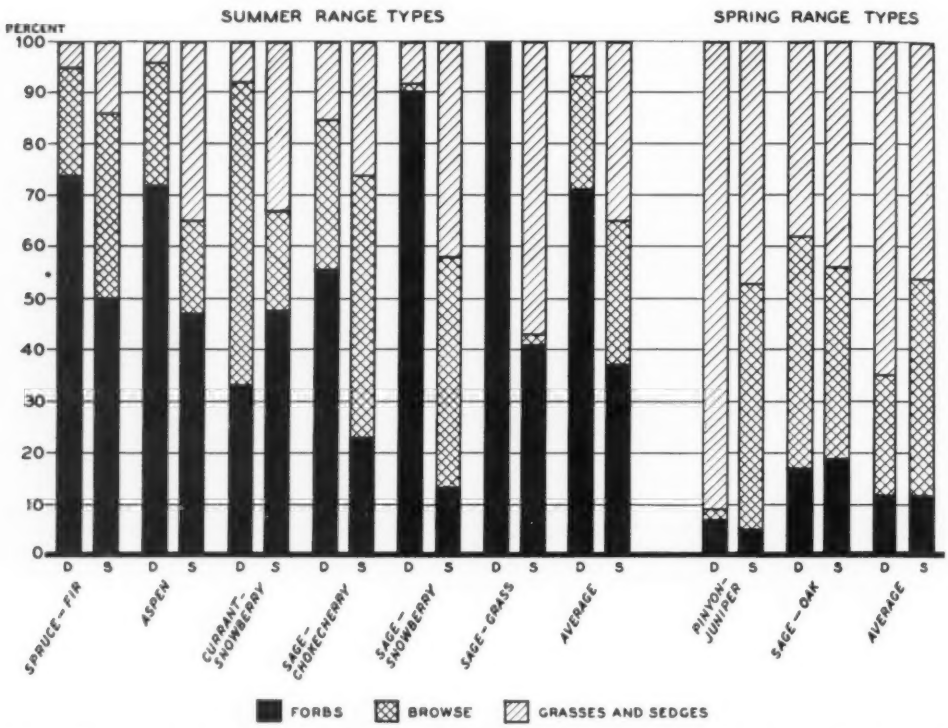

FIG. 1. Seasonal composition of deer (D) and sheep (S) diets, by classes of vegetation, in several vegetal types, 1947–50.

1949, and 1950 at four locations embracing two common vegetal types. These types, the sage-oak and pinyon-juniper, are characterized by the species listed below:

Sage-oak, Elevation 7,500 ft.—Big sagebrush, Gambel oak (*Quercus gambelii*), snowberry, lupine, bearded bluebunch wheatgrass (*Agropyron spicatum*), slender wheatgrass, smooth brome (*Bromus inermis*), and mutton bluegrass.

Pinyon-juniper, Elevation 7,500 ft.—Pinyon (*Pinus cembroides edulis*), juniper (*Juniperus utahensis*), big sagebrush, low sagebrush (*Artemisia arbuscula*), mountain-mahogany (*Cercocarpus montanus*), curlleaf mountain-mahogany (*C. ledifolius*), mutton bluegrass, and squirrel-tail (*Sitanion hystrix*).

Fifty species on the spring range were utilized; 15 were browse species, 24 forb, and 11 grass. This range is predominantly a browse type (Table 1) and while forbs made up half of the number of species utilized they represented only 5 percent of the total volume of forage available. The only forb that was sufficiently abundant to constitute 1 percent or more of the total forage was lupine. Grasses were also scarce; they composed 22 percent of the number of species eaten but only 11 percent of available food.

On the spring range, as on the summer

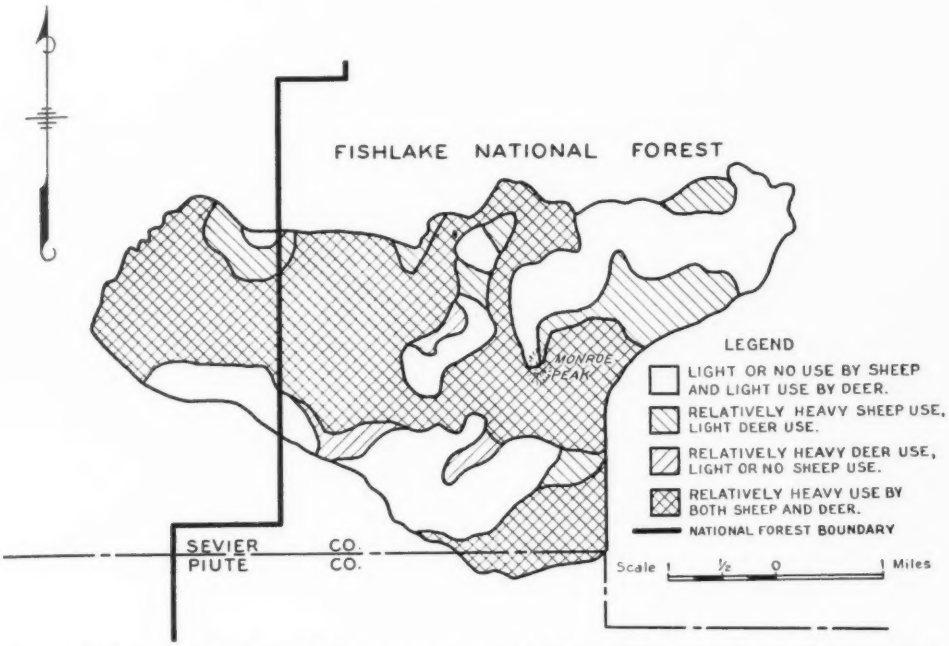
FISHLAKE NATIONAL FOREST
MONROE PEAK
LEGEND
LIGHT OR NO USE BY SHEEP AND LIGHT USE BY DEER.
RELATIVELY HEAVY SHEEP USE, LIGHT DEER USE.
RELATIVELY HEAVY DEER USE, LIGHT OR NO SHEEP USE.
RELATIVELY HEAVY USE BY BOTH SHEEP AND DEER.
NATIONAL FOREST BOUNDARY
SEVIER CO.
PIUTE CO.
Scale 1 ½ 0 1 Miles

FIG. 2. Distribution of deer and sheep grazing on the Monroe Mountain sheep allotment, Fishlake National Forest, central Utah, 1947–50.

range, the greater part of the diets of both deer and sheep consisted of only a few of the many species utilized (Table 5). Here, again, the importance of a few species is demonstrated by the fact that 8 species or fewer provided two-thirds or more of the diets in each type. In general the similarity in deer and sheep preference is not as pronounced as it was on summer range although 65 percent or more of each diet in the sage-oak type was made up of the same 9 species. In the pinyon-juniper type deer confined their diet almost exclusively to grasses while sheep utilized browse and grasses in about the same proportion.

The high percentage of grass which appears in the deer diet is possibly exaggerated because there was some indication that a few sheep had grazed in the immediate vicinity of the plots on one area. There was, of course, no way to separate deer use and sheep use. If a portion of the grass use attributed to deer was actually accomplished by sheep it is obvious that the percentage of grass as reported would be diminished in the deer diet and increased in the sheep diet. Proportions of browse and forbs in each diet would be changed accordingly. The only clue to the extent of deviation between the actual diet composition and that reported is indicated by data from the second of the two pinyon-juniper areas. No sheep grazed on this area and the grasses there made up three-fourths of the deer diet. This lends support to the belief that grasses occupied a prominent place in the deer diet at this season although

TABLE 5.—DEER AND SHEEP DIETS ON SPRING RANGE, 1947–50. (Diet figures are percent of total forage consumed by each class of animal as determined by weight and utilization estimates.)

Species	Vegetal type			
	Sage-oak		Pinyon-juniper	
	Deer	Sheep	Deer	Sheep
Artemisia nova	4	1	–	–
Artemisia tridentata	8	1	0	0
Cercocarpus montanus	26	17	0	35
Chrysothamnus lanceolatus	3	7	0	12
Purshia tridentata	1	3	0	0
Quercus gambelii	1	1	–	–
Castilleja linariaefolia	3	1	1	T*
Erigeron spp.	T	T	1	2
Agropyron cristatum	2	10	–	–
Agropyron spicatum	13	6	T	1
Poa fendleriana	4	11	82	39
Poa pratensis	9	7	–	–
Sitanion hystrix	8	T	1	2
Stipa comata	T	T	7	2
Stipa lettermani	1	3	0	1
Total	83	68	92	94

* Less than 1 percent.

their importance may be magnified by the data shown in Tables 4 and 5 and Figure 1. Of the six species most prominent in each diet one browse plant—mountain-mahogany—and three grasses—bearded bluebunch wheatgrass, mutton bluegrass, and Kentucky bluegrass (*Poa pratensis*)—were prominent in both diets (Table 4).

The minor importance of forbs in the spring diets of deer and sheep is illustrated in Figure 1 which shows that they averaged only 12 percent of the diet of each animal in the combined types. Grasses, on the other hand, composed nearly two-thirds of the deer diet and almost half of the sheep diet. Browse appeared in the spring deer diet in about the same proportion that it did in the summer diet, i. e., 23 percent, but in the sheep diet it was greater than in summer and was approximately equal to the proportion of grass. The low percentage of forbs in the spring diets is believed to be due to a scarcity of forbs in this area. Observation on other areas show that forbs are important as spring forage for both deer and sheep where palatable species are present.

In summary, 88 percent of the spring diet of each animal consisted of grasses and browse and there was great similarity in choice of species. If the animals grazed the same area at the same time these facts would inevitably lead to serious land-use competition, and to forage competition for Kentucky bluegrass which was utilized excessively. Actually, competition of both kinds was minimized by the differences in time of use and growth stage of the vegetation which were pointed out previously. An additional factor that tends to reduce the likelihood of conflict is the difference in areal use. About 13 percent of the 1,600 acres that make up the spring range on the study area was grazed by deer only, but the heaviest deer utili-

zation, as on the summer range, was found on the area used in common.

FALL AND WINTER COMPETITION

Sheep did not graze the Monroe winter deer range in the fall during the period of study so there was no question of fall sheep use conflicting with winter deer use on that area. However, the sheep grazed similar adjacent winter deer range immediately after leaving the Monroe area. Data collected there showed that oak, bitterbrush (*Purshia tridentata*) and mountain-mahogany were the major species grazed by sheep (29, 17, and 14 percent of the diet) with big sagebrush used very lightly (3 percent of diet). On the Monroe winter range sagebrush made up the bulk of the deer winter diet (64 percent), but mountain-mahogany utilization averaged 66 percent, oak 50 percent, and the scattered bitterbrush and fourwing saltbush (*Atriplex canescens*) were closely hedged both here and on the sheep-grazed range.

Where species palatable to both deer and sheep, as indicated above, are present fall sheep use can be expected to produce land-use competition with winter deer use at least on the type of range studied. For other species which are used by deer and are common on central Utah ranges such as big sagebrush, curlleaf mountain-mahogany, and juniper there would be little or no competition.

In Utah sheep are usually wintered at lower elevations than the foothill deer winter ranges. Occasionally, however, sheep do some winter grazing on midwinter deer range. No quantitative data are available on forage used by sheep in such cases but observations indicate very similar forage preferences of deer and sheep in midwinter. For example, observations of midwinter grazing on areas nearby and similar to the study area showed that both deer and sheep, of necessity, fed largely on the abundant sagebrush and that both sought out the scattered, more palatable shrubs such as fourwing saltbush and bitterbrush.

SUMMARY

Studies conducted in central Utah during 1947-50 to determine the nature and extent of seasonal competition between deer and sheep revealed the following relationships:

1. Deer and sheep each utilized a great many species, but two-thirds or more of their separate diets on spring and summer range consisted of 8 species or fewer.

2. In 4 out of the 6 vegetal types studied on summer range the same 8 species comprised more than half of each diet. Forbs provided 71 percent of the deer diet, browse 22 percent, and grasses and sedges 7 percent. In the sheep diet the three vegetal classes were more evenly divided; forbs accounted for 37 percent, browse 28 percent, and grasses and sedges 35 percent.

3. Six of the 10 species most prominent in each diet were also prominent in both diets. They were aspen, chokecherry, snowberry, clover, dandelion, and Letterman needlegrass.

4. On the spring range, grasses made up the largest part of both deer and sheep diets, although the reported findings possibly tend to increase their importance in the deer diet and decrease it in the sheep diet because of unavoidable circumstances discussed in the text. Forbs were of minor importance in each case (probably because they were

scarce) and the proportion of browse in the sheep diet was nearly twice as large as in the deer diet. Browse and grass together provided 88 percent of the spring diets of both deer and sheep and there was great similarity in choice of species.

5. Of the 6 species most prominent in each diet, 4 (mountain - mahogany, bearded bluebunch wheatgrass, mutton bluegrass, and Kentucky bluegrass) were prominent in both diets.

6. In their fall grazing, which takes place on deer winter range, sheep selected the same forage species that were subsequently chosen by deer in their winter grazing. Where winter range was used in common by deer and sheep, it was again apparent that their diets were much alike.

7. The similarity of deer and sheep diets is sure to cause conflict wherever the supply of preferred species is inadequate to satisfy the requirements of both animals. In addition, even though an adequate forage supply obviates any actual conflict, there is competition in the sense that if part of the deer population was removed, sheep numbers could be increased and vice versa. The probability of conflict is less on spring range which is used at different times and during different stages of vegetative growth than on summer range which is used at the same time and for a longer period.

8. Deer grazed over the entire study area of about 10,000 acres except for inaccessible rocky cliffs and ledges. Sheep used only 80 percent of the area because of insufficient or undesirable forage or unfavorable terrain. The greatest utilization by deer occurred on the area used in common.

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Accepted for publication June 30, 1952.

RACCOON PREDATION ON MUSKRATS NEAR CURRITUCK, NORTH CAROLINA [1]

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Since 1947-48, annual muskrat (*Ondatra zibethica macrodon*) harvests from Currituck Sound tidal marshes have become progressively smaller. Marshes adjoining woodlands have become especially unproductive. In one such area of 1,000 acres, the yield has shrunk 90 per cent during a five-year period.

Many marsh owners and trappers in the vicinity blame this decline upon the raccoon (*Procyon lotor lotor*). Complaints of this sort against the raccoon are familiar in other regions, but biologists are inclined to consider such reports exaggerated or unfounded. It is widely acknowledged that raccoons do take some toll of muskrats. Also, it is recognized that raccoon populations have been generally high during the past few years. 'Coons are definitely known to destroy muskrats found in traps and also to dig into nesting houses and devour the young. Evidence obtained near Currituck points to the raccoon as a main factor or the main factor depressing muskrat productivity. In this locality, the trappers' condemnation of the racoon appears justified.

Evidence of serious predation by raccoons was uncovered during an experimental demonstration of marsh improvement for muskrats. The study involved about 200 acres of privately owned and 791 acres of the state-owned, partially wooded Northwest River Marsh (about 400 acres of actual marsh) at the northwest end of Currituck Sound and on the Northwest River. Recognizing that seasonal insufficiency of water in these and many other marshes is an important factor limiting muskrat production, both directly and also by lowering the quality of marsh flora, effort was made to stabilize water levels by installing dikes. At the time the dikes were built, variable proportions of excellent muskrat food plants such as Olney three-square (*Scirpus olneyi*) and cattails (*Typha*, 4 species) were present in the flooded areas in combination with species of lesser quality such as needle-rush (*Juncus roemerianus*), sawgrass (*Cladium jamaicense*) and giant cordgrass (*Spartina cynosuroides*). The proportion of valuable plants increased substantially in 1950-1951 through the use of herbicides, controlled burning, and the direct effect of higher, stabilized water levels. Altogether, the diked marshes appeared to have much improved potentialities for muskrat habitation and it seemed reasonable to assume that increased populations would result.

[1] A contribution from Pittman-Robertson Wildlife Restoration Project 6-R, North Carolina Wildlife Resources Commission.

[2] The writer wishes to express grateful appreciation for the valuable assistance received from Dr. Alexander C. Martin. Leonard M. Llewellyn and Fred Dale made helpful suggestions.

Prior to completion of the diking projects, muskrat house counts on about 400 acres of state marsh disclosed a smaller number each successive year. Counts revealed 145 houses in 1948, 124 in 1949, and only 104 in 1950. In January 1951, after the largest diked unit had been flooded eight months and other dikes were a year or more old, house counts totaled 158, the largest number since the initiation of the study. Forty-three of the 158 houses were on 230 acres of undiked marsh and 115 were found on 170 acres of diked marsh, less than half of the study area. The largest diked unit (100 acres) had only 30 houses before flooding in 1950 but in 1951 there were 73. This increase in number of houses, together with noticeably increased muskrat sign, makes it seem evident that muskrats preferred the diked marshes to the undiked.

Similar response to diking was noted on privately owned Tice marshes on Tull Bay in the northwest corner of Currituck Sound, where a 20-acre marsh flooded by a dike in 1948 contained 38 muskrat houses. Because farmers complained (apparently without justification) that backed up water was flooding their land, the dike was destroyed in May, 1949 and subsequently the 20 acres of marsh supported only two muskrat houses. Despite the evidence that muskrats prefer diked marshes, population indications in the winter of 1952 in the recently diked state marshes did not bear out expectations. Of the 170 acres of diked marsh, only five acres were trapped the previous winter and it was expected that there might be at least 40 more houses than the 115 in the winter of 1951. Instead, there was a disappointing drop to 107 houses.

Evidence of Raccoon Predation

During the spring-summer-fall of 1951 while conducting a study of muskrat litter sizes, I discovered that a large number of the houses were damaged by raccoons. Of 213 muskrat houses examined in Currituck and Dare Counties during the seven-month period from April to October, 163 were on the state-owned Northwest River Marsh, 29 on Tice marshes, 17 on the Pea Island National Wildlife Refuge and 4 on the outer banks marshes near Corolla. An additional 116 houses on State and Tice marshes were examined early in December to determine the extent of damage done in this season while raccoons were still active but muskrat breeding was nil or negligible. Though many houses examined in the seven-month survey were found to have been invaded by predators, almost no damage to houses was noted during the winter months.

Damage to Houses in Northwest River Marsh: The first evidence of raccoon destructiveness occurred late in April, 1951 (Table 1). Six houses containing recently born young were under observation. Subsequent examination for tagging of the young disclosed that five houses had been dug open by raccoons and the baby muskrats were missing. No bone or hair remains could be found; only nest remains lay scattered over the houses. Considering that human activity might have led raccoons to the nests, 71 muskrat houses within the main dike and other undisturbed marsh were examined. But raccoons had located most of these

TABLE 1.—SEASONAL DAMAGE TO MUSKRAT HOUSES IN FOUR LOCALITIES

Locality and Raccoon Abundance	Month [1]	Number of Houses Examined	Occupied	Damaged	% of houses damaged
NORTHWEST RIVER MARSH	April	26	17	11	42
	May	71	48	59	83
	June	44	24	37	84
Raccoons very abundant	Sept.	22	10	7	32
	Dec.	74	74	1	1
TICE MARSH (Mainland)	July	6	6	6	100
Raccoons plentiful	Aug.	12	6	4	33
	Dec.	42	42	0	0
BRAY ISLAND Raccoons few	July	11	11	0	0
OUTER BANKS (Corolla and Pea Island) Raccoons few or none	July	21	21	0	0

[1] The bulk of muskrat production occurs during the late winter and spring, slackens off abruptly in July and August to almost no production during the remainder of year.

FIG. 1. Raccoon damage to muskrat house.

houses, too. Fifty-nine had been damaged, many beyond repair. None of the houses contained litters when observations were made.

During June, 1951, 44 houses were examined. Of these, 37 had been invaded by raccoons, and only 24 were occupied, the remaining 20 houses apparently vacated because of raccoon depredation. Of the 24 occupied houses, only one contained a litter, about two days old. Ten days later, the house was found opened by raccoon, nest parts lay strewn about and the young were missing. The fact that 22 of the 24 occupied houses had been searched by raccoons probably explains the presence of so few litters. No blood or hair remains were noticed at any of the damaged houses, but scattered nest remains at seven houses indicate that several litters had been found and eaten. It is also believed to be significant that of eight litters found during the study on the Northwest River Marsh, none was over a week old.

During the last week of September, 22 muskrat houses were searched for young muskrats. None was found. Of the 22 houses, 12 were unoccupied. Six of the unoccupied houses had been dug into by raccoons. Of the 10 occupied houses, 9 were undamaged and one had been opened. Digging sign at all seven molested houses was at least ten days old. Since houses checked were in a locality where racoon damage during the spring and summer was excessive, it seems significant, despite the small sample, that only one occupied house was found damaged. None of the houses contained young muskrats which might serve as predatory inducement to the raccoon.

Dwelling house counts made in December provided another opportunity to examine muskrat beds for damage while raccoons were still active. At this time, most houses had been completed about a month, although a few family units were still adding material. Of 74 occupied houses, only one had been opened by raccoons.

It seems particularly significant that raccoon damage to muskrat houses in the Northwest River marshes reached its peak in June at a time when parturition among muskrats is believed to be highest. During this period, 22 of 24 occupied houses examined for litters had been dug open by raccoons. In contrast to this, depredations were negligible in the winter when raccoons were still active but houses contained no young.

Damage to Houses in Tice Marshes: Twenty-nine muskrat houses were examined during July and early August; 11 on Bray Island (400 acres of marsh at the mouth of the Northwest River in Currituck Sound) and 18 on marsh on Tull Bay. Nine of 12 occupied houses on Tull Bay marsh—mostly bordered by swamp and heavily populated raccoon habitat—had been dug into by raccoons. Two of the three undamaged houses contained young, one with 2 and one with 6. None of the 11 dwellings on Bray Island had been disturbed by raccoons; in fact no sign of the animal was found and every house contained muskrats. Two litters were located, of two and one young respectively.

None of 42 dwelling houses on Tull Bay marsh examined early in December was found dug into by raccoons. Though only 6 houses were opened, none contained young. Again it was interest-

ing to note that raccoons were not damaging beds during the season when young muskrats were not available.

Damage to Houses in Outer Banks Marsh: Of the 21 houses examined on the outer banks, 17 were on the Pea Island National Wildlife Refuge below Oregon Inlet and 4 near Corolla. None of the houses had been dug into by raccoons and all were occupied by muskrats. Two Pea Island muskrat houses contained one and four young. All were large young about to leave the nest. Raccoons are not known to be present on Pea Island and their numbers near Corolla, until very recently, have been low.

It is noteworthy that the marsh at Corolla, where, judged by Northwest River marsh standards, muskrat foods are only fair, is normally one of the heaviest producing localities in the state. While muskrat yields have dropped off steadily in recent years on marshes where raccoon populations are heavy, the Corolla area and most of the outer bank marshes north to Virginia have been producing normal muskrat crops. (The 1951-52 muskrat crop, however, was very poor and trappers report numerous gray foxes and raccoons digging into beds.) Trappers in this favored location are disinclined to disclose their catch but according to fur dealers, much of the marsh on the outer banks, estimated at about 5,000 acres, produces upwards of two to five muskrats per acre. In contrast, the raccoon-infested Tice marshes of approximately 1,000 acres have not yielded an average of one muskrat per acre during the past five years. This difference in productivity is heightened by contrast in quality of habitat on Tice marshes; excellent habitat as on Tull Creek marsh is giving a low yield while comparatively inferior habitat having few or no raccoons is more productive. Figures illustrating this contrasting productivity are given in Table 2.

TABLE 2.—TRENDS IN MUSKRAT YIELD FROM ABOUT 400 ACRES OF MARSH ON BRAY ISLAND WHERE RACCOONS ARE SCARCE AND WHERE NO DAMAGED HOUSES WERE NOTED, IN CONTRAST TO YIELDS ON A 61-ACRE TRACT OF EXCELLENT BUT RACCOON-INFESTED MARSH ON TULL CREEK

Year	Bray Island Production	Tull Creek Marsh Production
	Raccoons Scarce	Raccoons Plentiful
	Muskrats per Acre	Muskrats per Acre
1948.....	.64	1
1949.....	.67	?
1950.....	.51	.2
1951.....	.68	.46

Indications from Age and Size Ratios of Muskrats: Age and size data from trapping records for the Northwest River Marsh furnish additional clues to the raccoon-muskrat picture. Since 1948, when the State of North Carolina acquired the Northwest River Marsh, only 211 muskrats have been harvested by traps, as follows: 1949, 56; 1950, 50 and 1951, 105. Of these, sex, weight, color and age data were obtained on 206. Of 54 muskrats trapped in 1949, 35 were adults and 19 subadults. Based on weights of more than 11,000 muskrats in the county during five seasons, twenty-three of the adults were considered large, weighing from 1,360 grams to 1,956 grams. The large size of adults was expected because the marsh had not been heavily trapped for at least two years, but the small proportion of subadults was puzzling.

In 1950, data on 50 muskrats revealed 29 adults and 21 subadults and in 1951, records for 102 muskrats indicated that 73 were adults and only 29 subadults. Totals for the three-year study show 66.51 adults for every 33.49 young. The relatively small number of large family-type dwelling houses on the Northwest River Marsh in recent years and the preponderance of adult muskrats among those trapped indicate a low population of young muskrats. Three consecutive years of lopsided age ratios made it appear certain that if litter sizes were normal, survival must be poor.

OTHER POSSIBLE FACTORS OF DECLINE

Sterility: The three-year period of abnormal adult-juvenile ratios suggested the possibility of sterility. During the winter of 1950-51 the uteri of 19 adult muskrats trapped from the Northwest River Marsh were examined, disclosing placental scars or corpora lutea on 16 and no visible scars or corpora lutea on 3. Fading caused by the formaldehyde made accurate scar counts impossible. The study sample, however, revealed that the majority of adult female muskrats on the Northwest River Marsh are successful breeders. Furthermore, nesting studies made during 1951 proved that their young were being born.

Disease: Since muskrat yields have been low for at least a decade on most tidal marshes in Maryland, the possibility of decimation by disease has been considered. That an epizootic is causing low muskrat yields on mainland tidal marsh in Currituck County is discounted for the following reasons:

(1) Search of hundreds of occupied and unoccupied muskrat houses during the past four years has not revealed the remains of a single muskrat.

(2) While muskrat production is down in most tidal marsh acreage, farmland ditches all over the county consistently produce normal muskrat yields. If an epizootic were operating in marsh habitat, it is logical to believe it would also strike ditch-dwelling muskrat populations. On the other hand, though it is comparatively easy for raccoons to locate young muskrat litters in marsh houses, it is more difficult to get at them in underground tunnels.

(3) If disease were the explanation, its effects would be noticeable not only in partially wooded marshes where raccoons abound, but also on the Pea Island National Wildlife Refuge where raccoons are absent and muskrats are plentiful.

OTHER PREDATOR-PREY RELATIONS IN INVADED MUSKRAT HOUSES

Muskrat houses in the Northwest River area, and especially unoccupied ones, frequently housed rice rats (*Oryzomys palustris palustris*), meadow mice (*Microtus sp.*) and very likely other small mammals. A large percentage of unoccupied houses may, therefore, have been dug into for the young of these animals. Evidence of raccoon digging for rodents housed just beneath the external wall in occupied muskrat houses was also noted, and on occasions the appearance of shallow cone-like holes looked as though raccoons or mink might have been burrowing for insect larvae. Neither of these types of diggings was recorded in Table 1. Where a house was patched, however, and about 60 percent of them were, the observation was recorded as raccoon damage. During

nearly five years of study in this vicinity, the writer has found fewer than a half dozen houses burrowed into by mink, though mink are common in the area. Otters are also common in the State refuge and though trappers report that they often rip open muskrat beds, no evidence of this has ever been found by the writer anywhere along the coast. There is evidence, however, that otters occasionally rest on muskrat houses and commonly use them (mostly collapsed dead houses) as defecating posts. Gray foxes even during winter periods of low water seldom frequent marsh in the Northwest River area. Wandering dogs periodically dig into and completely destroy a few muskrat houses.

SUMMARY

Evidence against the raccoon as a muskrat predator in the Currituck marshes consists of a series of incriminating circumstances. Further substantiation of the raccoon's harmful role might become available if it were readily possible to exclude the animal from marshes where it is now plentiful. However, as a substitute of such confirmation, there is evidence from a natural "control" consisting of the muskrat marshes in the nearby coastal reef where raccoons in many localities are scarce or absent.

The various converging lines of evidence may be summed up as follows:

1. Raccoon populations in eastern coastal sections have been high in recent years.

2. In many Currituck marshes that formerly were productive but are frequented by raccoons, muskrat harvests have invariably been low recently. Even in marshes improved by diking, muskrat populations have remained relatively low. In one improved marsh, the number of houses more than doubled a few months after flooding, but subsequent muskrat populations did not rise as anticipated.

3. In marshes on the nearby outer banks where raccoons are scarce or absent, muskrat productivity has maintained a fairly even and normal level.

4. During summer, in raccoon infested marshes, most muskrat houses were dug into by raccoons. Damage to muskrat houses by mink, foxes, dogs and other predators is distinguishable from that of raccoons.

5. During summer, in marshes on outer banks, (largely void of raccoons), no muskrat houses were found damaged.

6. In December, in marshes frequented by raccoons, there was practically no damage to muskrat houses—indicating that in other seasons raccoon invasion of muskrat houses was influenced by search for young.

7. In localities where raccoons were present but where muskrats lived in burrows instead of houses readily accessible to raccoons, muskrat populations remained normal.

8. Studies made on age and weights of Currituck muskrats indicate an abnormal preponderance of adults and a scarcity of young.

9. Placental examination and the presence of litters in the spring and summer proved that they were breeding successfully. These data rule out sterility as the explanation for the scarcity of young.

10. There is no evidence that an epizootic is causing the present low muskrat population.

Accepted for publication May 5, 1952.

CONSUMPTION OF CEREAL GRAINS BY MIGRATORY WATERFOWL

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A review of the literature reveals little or no information on the amount of food consumed by wild waterfowl. Such information would be useful in evaluating waterfowl food resources and in planning management programs. The need for information of this kind is of particular interest in those areas where cereal grains have become a substantial part of the fall and winter diet of waterfowl (Colls, 1951; Day, 1944; Horn, 1949; Singleton, 1951; Wagar, 1946). Where natural foods are in short supply it may become necessary to alleviate crop depredations through habitat management (Gordon, 1950; Leitch, 1951), and in such instances a knowledge of the quantities of cereal grains consumed by waterfowl would be useful to the manager. Herewith are presented some observations on the consumption of cereal grains by representative species of captive wild waterfowl during the period, 1949-1951, at the Natural History Survey Laboratory located on the Chautauqua National Wildlife Refuge near Havana, Illinois.

These data were taken from records on the rate of food consumption by healthy wild birds being held in captivity in connection with an investigation of lead poisoning in waterfowl (Jordan and Bellrose, 1951). The birds were held in large, wire-enclosed pens and were exposed to all elements of weather. Game-farm and wild mallards, *Anas platyrhynchos* L., blue-winged teals, *Anas discors* L., and Canada geese, *Branta canadensis* (L.) were generally penned in groups of at least 10 birds each; each group was provided with a constant supply of running water piped into large metal tanks 6 feet long, 3 feet wide, and 1 foot deep. The several diets made available to the birds included whole yellow corn, mixed grains (wheat, 64 per cent; corn, 24 per cent; and lesser amounts of oats, sorghums, soybeans, flax, rice, and cow peas), small grains (mixed grains less corn, soybeans, and cow peas), tame rice, and commercial duck pellets. Food was supplied in wooden boxes and the amounts consumed were accurately recorded each day, or at intervals of 2 or 3 days.

The average daily amounts of food consumed by wild mallards are shown in Table 1. The values shown are representative of ducks exposed to average weather conditions for central Illinois. In Table 2 the average food intake of mallards is compared with that of blue-winged teals and Canada geese.

Air temperature exerted an important effect upon the amount of food consumed by the captive birds. A comparison of records from all seasons of the year revealed that the amount of food eaten by mallards varied inversely with the seasonal level of air temperatures. The available records indicate

[1] In cooperation with Olin Industries, Inc.

TABLE 1.—AVERAGE DAILY FOOD INTAKE, BY SEASONS, OF ADULT DRAKE WILD MALLARDS HELD IN CAPTIVITY AND FED DIETS OF CEREAL GRAINS

Diet	Season	Av. Daily Food Intake—lbs.	Waterfowl-Days
Corn	Late Summer (Aug.)	0.08	48
	Early Fall (Oct.)	0.13	60
	Winter (Dec.)	0.16	120
Small Grains	Late Spring (Apr.-May)	0.12	315
	Early Fall (Oct.)	0.16	70
	Winter (Dec.-Jan.)	0.18	140
Tame Rice	Winter (Febr.)	0.17	60

TABLE 2.—COMPARATIVE FOOD INTAKES, BY SEASONS, OF MALLARDS AND BLUE-WINGED TEALS, AND MALLARDS AND CANADA GEESE HELD IN CAPTIVITY AND FED DIETS OF CEREAL GRAINS

Species	Diet	Season	Av. Daily Food Intake—lbs.	Waterfowl-Days
Mallards *	Mixed Grains	Early Fall (Oct.)	0.15	50
Blue-Winged Teals **		Early Fall (Oct.)	0.06	105
Mallards *	Corn	Late Fall (Nov.-Dec.)	0.20	60
Canada Geese ***		Winter (Jan.)	0.40	102
Mallards *	Small Grains	Winter (Febr.)	0.14	70
Canada Geese ***		Winter (Febr.)	0.36	119

* Adult drakes.
** Juvenile drakes.
*** All-age classes of males and females.

that the other waterfowl in these experiments responded similarly. Maximum food intake was attained during periods of below-freezing weather in late fall and winter.

Results of these experiments indicate that under average weather conditions occurring in early fall, mallards in nature will consume, if available, an average of about 0.16 pound of small grains, or 0.13 pound of corn, daily. During the colder weather of late fall and winter the intake of small grains would increase to about 0.18 pound per bird, whereas that of corn would increase to about 0.16 pound. The consumption of tame rice is likely to approximate that of small grains at all seasons. Allowance should be made for increased rates of intake during periods of abnormally cold weather, as for example, when air temperatures reach 15 degrees F., or lower. The maximum intake of corn by captive mallards in a single day was recorded on November 23, 1950 when 20 drakes consumed an average of 0.33 pound each. A similar amount of small grains was taken by each of 20 other drakes on this same date. In these instances high food intake was associated with a period of strong winds and snowfall accompanied by a fall in air temperatures of about 20 degrees F.

The consumption of corn and small grains by Canada geese in winter averaged 0.40 and 0.36 pound, respec-

tively, or roughly twice the amount taken by drake mallards. The maximum amount of corn consumed by each of 17 geese averaged 0.52 pound on January 21, 1951 when air temperatures fell from a high of 33 degrees to a low of 5 degrees F. in about 21 hours.

A sex-related difference in food consumption was found in mallards. Captive wild drakes consumed about 15 per cent more food than did hens during the fall and winter months. Thus, at this season of the year, a population of wild mallards in which the sexes were evenly divided theoretically would be expected to take about 7.5 per cent less food than that shown for drakes in Table 1. The sex-related difference in food consumption for fall and winter was reversed during the spring breeding season. For a period of 6 weeks between April 16 and May 28, 1951, 15 hens took an average of 16.6 per cent more food than did an equal number of drakes. This may have represented a minimum difference because wild hens laid no eggs while in captivity, and may not, therefore, have required as much additional food as if they had been laying. Five game-farm hens in egg production consumed an average of 75.9 per cent more food than did five breeding drakes, and the hens gained weight during the egg-laying period. The average food intake of four incubating hens, however, was about one-fourth the amount taken by laying hens, and less than half that consumed by breeding drakes. The low level of intake by incubating hens was accompanied by losses in body weight.

An age-related difference in food intake was revealed in an experiment with game-farm mallards on a diet of commercial duck pellets. Rapidly growing ducks between the ages of 8 and 9 weeks consumed 44 per cent more food than did adults.

For a period of 5 days in the latter part of October, each of 21 blue-winged teals consumed an average of 0.06 pound of mixed grains per day. The teals, however, made little or no use of the large seeds in the mixture. On a previous occasion when the teals were extremely hungry, having had virtually no food for 4 days, all sizes of seeds in this diet were readily accepted. Similar food habits were observed in recently captured mallards that had undergone self-enforced abstinence from food, and in mallards deprived of food for various lengths of time.

The food intake of captive waterfowl seemed to be more or less directly related to body weight. For example, during February, 1951 the body weight ratio between 10 drake and 10 hen mallards averaged 1.23 to 1 (2.92 pounds to 2.38 pounds), and the ratio of food consumption between the sexes for the same month averaged 1.15 to 1 (4.31 pounds to 3.76 pounds). In another case the average weight of 10 drake mallards was 3.19 pounds, whereas that of 21 blue-winged teals was 1.04 pounds, or a body weight ratio between the species of 3.1 to 1. The food intake of the mallards, however, was only 2.5 times that of the smaller teals during this same period of time (Table 2). The relationship was somewhat better balanced in the case of mallards and Canada geese. The ratio of body weights between geese and mallards was 2.4 to 1 (7.20 pounds to 2.94 pounds) whereas the ratio of small grains intake during February was 2.6 to 1 (Table 2). This

suggests that the rates of food intake presented in Table 2 may be used in making rough interpolations of the probable food demands of other species on the basis of average body weight.

It is thought that if these data on food intake are used in conjunction with determinations of the amount of food available to waterfowl in nature, the carrying capacity of some food resources may be evaluated in terms of duck-days with a fair degree of accuracy. The cereal grains are especially well adapted to this kind of evaluation. Agricultural studies have shown that an average of about 10 per cent of the corn crop is wasted during mechanical picking (Pickard, 1952) and a 3 to 4 per cent loss occurs in harvesting wheat (McCuen and Huber, 1952). The crop yields of natural waterfowl food plants have been measured by Low and Bellrose (1944) and Singelton (1951), and these could be expressed in terms of waterfowl-days of available food.

Allowances for variations in food demand arising from changes in local weather conditions and in the sex and age components of waterfowl populations may be difficult or impossible to make. For practical purposes, however, it would appear advisable to evaluate food supplies on the basis of the demands of adult males during average weather conditions for any given season of the year. In this manner a rough appraisal could be made of food supply as a factor limiting the carrying capacity of specific areas for waterfowl.

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Accepted for publication June 13, 1952.

A DETERMINATION OF HOLE SIZES WHICH EXCLUDE CERTAIN PREDATORY MAMMALS[1]

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On several occasions the authors have been called upon to give information to poultry raisers relative to fencing material which will give protection against various kinds of predatory mammals. One type of poultry rearing, the range-shelter method, is particularly vulnerable to the depredations of carnivorous mammals including domestic cats and dogs. Under this kind of management large numbers of chickens are placed on open pasture range and supplied at intervals over the area with roosting shelters consisting of a metal roof and sides usually of woven wire. When the fowls enter these shelters at dusk, an attendant fastens a door to secure them, and releases them early in the morning. Thus the birds are generally safe from night predators although the degree of safety may depend upon numerous environmental conditions such as location of the range relative to cover, dens, etc.; strength of the wire and size of mesh; predator density; and vigilance of the attendant. Of all these, perhaps the one condition easiest to control, and when controlled will provide greatest safety, is the sound construction of shelters.

To construct a predator-proof shelter with sides and bottom of wire requires some knowledge of the kind of material that will exclude possible raiders. The repellent qualities of the wire must be known in terms of wire size as well as mesh size. There are so many differences in predator sizes and methods of attack that the poultry man for convenience may settle upon a popular material such as 2-inch or even 1-inch mesh poultry netting neither of which is a real barrier to any predator; or he might choose 1-inch fox netting of 16-gauge wire, more than adequate against all predators except small weasels. Since wire fencing is sold by weight, smaller meshes and heavier gauges are more expensive. For economy in the initial cost of construction, it is therefore desirable to know what predators one has to contend with.

This study was done to secure data useful as a guide in making recommendations concerning the maximum size of fence mesh necessary to exclude subadult or adult predatory mammals commonly found in this region. The procedure was to use several different animals of the same species to determine the minimum dimensions of rectangular or circular holes that a species could pass. Thus, in either shape, the hole of the next smaller size preventing passage would be the maximum mesh size for fencing to exclude that species.

[1] Journal Paper No. 614 Purdue University Agricultural Experiment Station, in cooperation with the Indiana Department of Conservation which furnished many of the experimental mammals. We are also indebted to Richard N. Sheek for assistance in the experiments.

Experimental Procedure

The equipment consisted of two sets of two adjoining cages. One set was built specifically for holding weasels, the larger cage of which measured 13 x 15 x 20 inches and the smaller 6 x 6 x 20 inches. These cages had metal frames and were covered with 1/4-inch mesh hardware cloth. The other set built for larger animals included a larger cage 28 x 36 x 36 inches and a smaller one 12 x 12 x 20 inches both covered with 1 x 2 inch electric welded 14-gauge fabric. The weasel cage was fitted with guides for the insertion of a sliding panel of 5/8-inch hardwood, and different panels were bored with holes from 3/4 to 1-1/4 inches in diameter. The weasels were not tested with rectangular holes.

The larger set of cages was fitted with removable metal panels between cages. One of these panels mounted two sliding plates, released or locked in place by wing nuts, permitting the formation of a rectangular hole ranging from 1 x 1 to 4 x 4 inches. The other panel mounted removable plates having circular holes 1 to 5 inches in diameter.

The animals tested were obtained either as wild, live-trapped individuals, from game farm exhibition pens, or in one case as a pet. The procedure was to place the animal in either cage, usually the smaller, and to induce the animal to try the passage between the cages by enticing with food and water, or by some form of mild stimulation. At the start the hole was set large enough so that the animal could readily pass it and become accustomed to the somewhat greater liberty of both cages. The hole was then contracted until the animal could no longer get through. When the barring size was found, the dimension was increased by 1/4 inch increments (or 1/8 inch in case of the weasels) until passage was observed several times to indicate that the animal was not being bound by the aperture.

After the minimum size of hole was determined, the animal was anesthetized with ether, sexed, weighed, and maximum head width and height measured. One raccoon was sacrificed after these live measurements to secure the same measurements after death and after skinning. For the raccoons a measurement was also taken across the widest part of the hip region, the caliper jaws being placed external to the heads of the femurs.

A total of 21 individuals from 7 species of mammals were used in these tests. The tests were made indoors with cages resting upon a concrete floor and in view of daily human activity in the laboratory.

Results and Discussion

In addition to the essential data shown in Table 1, the behavior of the animals being tested is of interest.

The time required for determination of the minimum hole permitting passage varied from 2 hours in case of a skunk to 2 weeks in case of a raccoon with wide variation in response among the different species and individuals of the same species. The skunks (deodorized) were easily frightened by rattling of paper or stamping of feet, and could be forced through the holes easily by this type of stimulation. At first the foxes and weasels also made great efforts to escape through the holes when frightened, but soon became belligerent and defensive at the slightest provocation.

TABLE 1.—SUMMARY OF ANIMAL DIMENSIONS AND THE MINIMUM SIZES OF HOLES THEY PASSED

Species and Sexes	Number Used and Weight Ranges **	Head Height Ranges (inches)	Head Width Ranges (inches)	Minimum Hole Passed (inches)	
				Rectangle	Circle
Virginia Opossum * *Didelphis virginiana* F	3 2-1/2 - 4-1/2	1-1/8 - 2	2-1/4 - 2-5/8	2 x 2-1/2	2-3/4 (diam.)
Raccoon *Procyon l. lotor* F	3 9-1/2 - 10	2 - 2-1/4	2-3/4 - 2-7/8	3 x 3-1/2	3-1/2
N. Y. Weasel *Mustela novaboracensis* M,F	5 100 - 200	10/16 - 15/16	3/4 - 1	.....	7/8
Mink *Mustela vison mink* M	1 2-1/10	1-3/8	1-11/16	1-1/2 x 2	...
Eastern Skunk *Mephitis nigra* M,F	3 2-3/4 - 3-3/4	1-5/16 - 1-1/2	1-11/16 - 1-13/16	2 x 2-1/2	2-3/4
Red Fox *Vulpes fulva* M,F	4 7 - 10-1/2	2-1/16 - 2-7/8	2-9/16 - 3-3/16	3 x 3	3-1/2
Gray Fox *Urocyon cinereoargenteus* M,F	2 7-3/4 - 9	2-3/16 - 2-3/8	2-5/8 - 2-7/8	2-1/4 x 3-1/4	3-5/16

** In pounds except N. Y. Weasel in grams.
* Nomenclature after M. W. Lyon. 1936. "Mammals of Indiana".

The opossums, a wild raccoon, one gray fox, and two red foxes were sullen, and the carnivores were definitely aggressive. Most of the efforts made by these animals were at night in response to food or water placed in the larger cage. It was not uncommon for the animal to make the passage from smaller cage to the larger, consume the food or drink water, and return to the smaller cage as if to its lair. The weasels often slept soundly during the day, and with one exception preferred the smaller cage.

The mink drowsed through the day, and if aroused would defend itself briefly before attempting escape. Both mink and weasels screamed in apparent exasperation even when unprovoked, the weasels especially when fighting a difficult hole. It is probable that the 5/8-inch thickness of the hardwood panel presented more friction to the weasels' bodies than a similar aperture in thinner metal.

Determined struggle in attempting to pass the holes was characteristic only of the raccoons, weasels and both fox species. On their own initiative these species often became temporarily bound at thorax, abdomen, or pelvis while straining forwards or backwards. The wire bottoms of both cages provided foot and claw holds which assisted in pushing or pulling, but these animals also made complete revolutions while in the hole, the hind feet using side and top surfaces of the cages as well.

As a rule of the thumb for some

mammals it is thought that the head is the limiting part of its anatomy, but our observations indicate that this is not the case for our test animals. The opossums, mink, skunks, and foxes were bound by their shoulders. In those cases the head and one or both fore feet could be passed through as far as the upper arm, but the scapular region stopped the passage. The raccoons were always held up by the pelvic region, this part only barring their passage through some holes, and in case of the weasels, the shoulders or the pelvis barred passage depending upon the individual.

One of the raccoons could not pass a 3-1/2-inch circle, being hindered by its pelvic width, but was able to reach through and grasp food 19 inches distant from the hole. The same raccoon also failed to pass a wood duck box hole sawn as a 3 x 4 inch oval, but after relaxing anesthesia, the animal was pulled through the hole without much difficulty. The data in Table 2 are further indication that muscle tone influences the dimensions of raccoons which are slightly smaller after death. The differences before and after skinning are attributable to thickness of the hide. The dexterity of the raccoon is related to its success as a predator, and its ability to reach into holes and grasp objects renders wood ducks and other hole-nesting species especially vulnerable to raccoon predation.

No correlations existed between body weight and circle diameter, between skull size and circle diameter, or between skull size and hole area or diagonal of rectangular hole. As an example of no relationship between animal size and hole size, one 10-pound raccoon passed a 3-1/2-inch circle but another of the same weight required a 4-1/4-inch circle. In the second, both head measurements were 1/8-inch smaller but pelvic widths were the same. Such differences in performance from animals of nearly comparable build suggest wide variation in the same species in temperament, strength, coordination, and perhaps learning ability, none of which the equipment used could test. Immature individuals might invalidate these determinations depending upon their aggressiveness at weaning time and later.

Table 2.—Comparative Measurements of a Raccoon Under Anesthesia and Before Rigor Mortis When Dead

	Head Width	Head Height	Pelvic Width
Before death....	2-15/16	2-1/4	3-1/2
After death.....	2-7/8	2-3/16	3-3/8
After skinning...	2-3/4	2-1/8	3-3/16

The testing of strength of fencing materials was abandoned after difficulties were met relating to the equipment and temperament of the animals. There are innumerable varieties of fence and wire cloth manufactured utilizing all gauges of wire, mesh size and shape, and different methods of joining cross wires. All of these mechanical features influence the repellent ability of the fence. The conditions used were highly artificial relative to an animal forcing entry from a free-living state and are perhaps more applicable to the restraint of captive animals. In the latter case, larger cages permitting greater freedom would be more likely to contain the animal safely behind the same strength of wire. On the basis of our experience, a material offering more than adequate barrier to entry of opossum, raccoon, skunk, red fox and gray fox would be

14-gauge 1 x 2 inch mesh electrically welded wire fabric. In the case of mink and weasel, 20-gauge 1/2-inch mesh wire cloth will suffice.

SUMMARY

To determine the size of fence mesh prohibiting passage of wild predatory mammals, twenty-one individuals comprising seven predatory species were tested to find the size of the smallest holes they could pass. Most of the mammals were considerably larger than weanlings so the results are only strictly applicable to the animals tested. No correlation existed between body dimensions and hole dimensions or area. The findings indicated that all species tested were adequately barred by 14-gauge 1 x 2 inch mesh electrically welded wire fabric except small mink and weasel; the latter species would be stopped by 20-gauge 1/2-inch wire cloth.

Accepted for publication April 8, 1952.

EFFECT OF VERTEBRATE ANIMALS ON SEED CROP OF SUGAR PINE

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The sugar pine, (*Pinus lambertiana*), growing principally in mountains of central and northern California and southern Oregon, is the largest and grandest of pines. Its stately beauty and the high quality of its lumber make it a valued species to which silviculturists give particular attention. Yet nearly everywhere reproduction is scanty. Rodents have been accused of taking much seed, but little information is available on the extent or significance of losses attributable to vertebrate animals.

Haig, Davis, and Weidman (1941) state, in respect to the western white pine type, that the "total effect of the various agencies causing seed losses on natural regeneration is indubitably great, and it is unfortunate that so little is known about them. Better information . . . is necessary for accurate evaluation of the efficacy of seed trees."

In the fall of 1951, the Department of Zoology of the University of California at Davis in cooperation with the California Forest and Range Experiment Station of the United States Forest Service studied the effect of vertebrate animals on the sugar pine seed crop of that year. Twenty mature cone-bearing trees growing about a quarter of a mile apart in a mixed coniferous forest near Lake Almanor in Plumas County, California were marked. On five dates between August 14 and September 23, the numbers of healthy cones on the marked pines were counted, the fate of those missing was determined, the activities of seed-eating animals were

observed, and the stomach contents of rodents trapped on the area were analyzed.

Selective logging over a period of years had opened up the forest and had favored wildlife; rodents and birds were abundant. The numerically dominant conifers, *Pinus ponderosa* and *Abies concolor*, produced almost no seeds during 1951; in consequence, the few sugar pines which bore cones attracted a variety and quantity of seed-eating animals.

When the green and tightly closed cones were first counted on August 14, there had been no depredations by vertebrates. (A small loss attributable to insects and fungi does not come within the scope of this study). At that time, the twenty pines bore 1,656 healthy cones. The maximum for a single tree was 358, the minimum 8, and the average 85. On the basis of 230 seeds per cone (Fritz, 1947), the estimated potential seed production from the twenty marked trees was 380,880.

About August 27, some two weeks before the cones began to open, pine squirrels (*Tamiasciurus douglasii*) began to cut down cones. As expressed poetically by Seton (1909), these energetic rodents must do their harvesting before the cones open, otherwise the seeds "take wings unto themselves and fly away." The squirrels worked vigorously and with speed. Instead of descending immediately to remove seeds from each cone dropped, they left many on the ground for days while continuing to labor high in the tree tops.

One reason for haste was competition with white-headed woodpeckers (*Dendrocopos albolarvatus*). Moving through the forest in small groups of four to six, these birds slashed open every cone on which they alighted and ate the seeds, leaving deep vertical trenches (Fig. 1). A related bird in Denmark, the great spotted woodpecker, attacks fir, spruce, and larch (Boaz, 1896).

Undamaged cones opened and shed seeds by the middle of September.

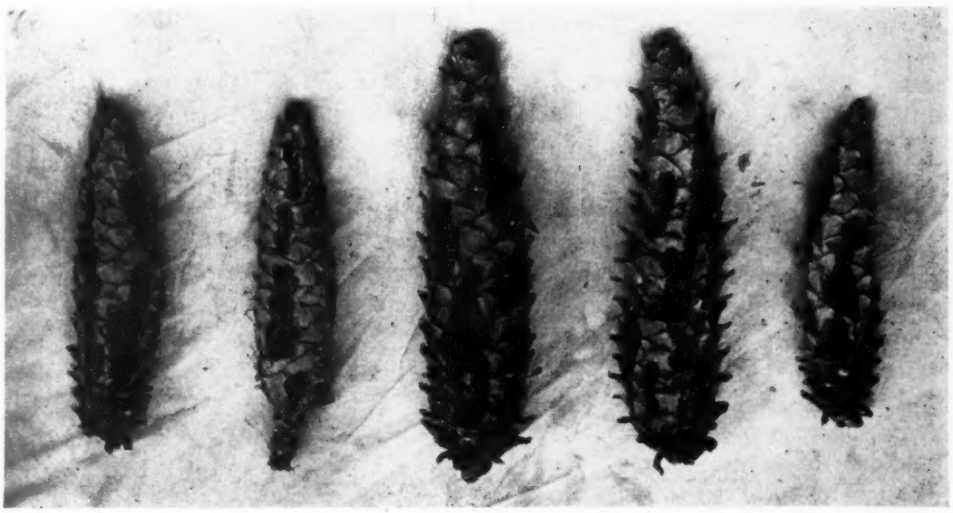

FIG. 1. Sugar pine cones damaged by white-headed woodpeckers, which extracted all seed.

Squirrels then ceased to cut them, and woodpeckers sought other food.

At that time a summary of extent of depredations by these two animals revealed that, of the original 1,656 healthy cones, 896 (54%) were cut by squirrels, 559 (34%) were destroyed by woodpeckers, and 201 (12%) survived to shed seeds.

The average number of cones that opened per tree was 10, but some pines suffered greater losses than others. One bearing 96 cones had not more than 11 damaged. while another that began with 358 opened only 15. Seven pines lost all their cones either to squirrels or woodpeckers or both.

Cones cut by squirrels were found at the base of every tree, but woodpeckers visited only half the pines. They tended to concentrate on certain trees. For example, on one pine they destroyed 252 cones, which was 85% of the original 358.

When the few cones that escaped squirrels and woodpeckers began to open, they were attacked by Steller jays (*Cyanocitta stelleri*). In a typical assault a jay, launching itself from a nearby branch, struck an open cone repeatedly until a seed was dislodged. Then, swooping down, it seized the morsel in midair, carried it to a limb, pounded the shell open, and ate the kernel. I counted ten jays at one pine. They were aggressive and vociferous. A few days later when all seeds at that site had been consumed, not a jay was to be seen or heard, but a few miles away a tree shedding seeds was the center of an avian uproar.

Because of hot, dry weather in mid-September, many of the cones cut and dropped by squirrels opened on the ground before the rodents were able to strip off the bracts and remove the seeds. These self-opened cones attracted white-breasted nuthatches (*Sitta carolinensis*), red-breasted nuthatches (*Sitta canadensis*), and mountain chickadees (*Parus gambeli*). So long as the supply lasted, the birds labored throughout the daylight hours, flying to the ground to pull seeds from cones and carry them away to be eaten or, in most instances, stored for future use. One chickadee that I timed made twelve trips in ten minutes. Usually a nuthatch, when removing a seed from a cone, would grasp the wing and manipulate the seed until it was securely held with the wing directed forward. The red-breasted nuthatch was most aggressive. Often by diving at a chickadee it scared the latter into surrendering seeds.

Seeds scattered through ground litter —either dropped accidentally by nuthatches, chickadees, or jays, or shed from the few undisturbed cones—were sought during the day by three species of chipmunks (*Eutamias amoenus*, *E. speciosus*, and *E. townsendii*) and during the night by white-footed mice (*Peromyscus maniculatus*). These rodents covered the ground assiduously, poking their noses under litter and investigating every square inch again and again. On finding a seed, a chipmunk would bite off the wings and pouch it. When the pouches were full it would scurry away to cache the prize.

Mantled squirrels (*Citellus lateralis*) were numerous, but study of stomach contents indicated they ate less seed than did mice and chipmunks. Unlike the latter, they disliked to search for relatively small, scarce objects.

To summarize the effect of verte-

brates on the 1951 seed crop of sugar pine at Lake Almanor: closed cones on trees were cut by pine squirrels and slashed by white-headed woodpeckers; seeds were extracted from open, pendulous cones by Steller jays and from open ones on the ground by white-breasted nuthatches, red-breasted nuthatches, and mountain chickadees; and shed seeds were hunted in litter by chipmunks, white-footed mice, and, to a lesser extent, mantled squirrels. It appeared that almost no seeds survived from the estimated potential crop of 380,880. I would not expect to find a seedling of sugar pine under any of the marked trees in the spring of 1952.

This study demonstrated that in a mixed coniferous forest where light logging has created favorable conditions for wildlife and during a year when a few sugar pines are the only trees having cones, rodents and birds can destroy practically all seeds produced by those valuable conifers. Presumably, reproduction of sugar pine at Lake Almanor occurred in the past when a reduction in the numbers of birds and rodents coincided with a heavy seed production by all conifers and with other favorable conditions.

I am grateful to Dr. Tracy I. Storer for assistance with this paper.

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Accepted for publication May 15, 1952.

SOME ASPECTS OF THE POPULATION ECOLOGY OF BREEDING MOURNING DOVES IN GEORGIA *

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The present study was undertaken to test the spot-mapping method of population measurement on restricted study areas, and to obtain preliminary estimates of the current abundance and production of doves on a unit-area basis in Georgia. The spot-mapping method, originated by the late A. B. Williams (see summary by Williams 1947), has proved very useful in measuring population density of many territorial bird species and also for total (mixed species) populations of small birds. During the breeding season doves do not restrict their activities to small defended territories as do many birds, but they make themselves conspicuous in the vicinity of nesting sites and thus are easily spot-mapped. Few attempts have been made to determine what modifications of technic are needed for doves, or indeed if breeding density can be determined in this manner.

Area studies have their advantage over call-counts and road-counts in that actual density is determined on a unit-area basis. While it may often be sufficient to know whether doves are increasing, decreasing or holding their own in a given region, it would seem important, for breeding populations at least, to determine the actual number, since some of the important factors affecting populations may differ regionally or may be density-dependent. The present study was also undertaken to provide "calibration" for call-counts being carried out in the same region.

Field work on the coastal plain was jointly supported by the State Game and Fish Commission and the Emory Field Station which served as a base of operation. Field work on the piedmont was aided by travel funds supplied by the Game and Fish Commission, with the University of Georgia serving as a base of operation. The authors are indebted to Major Melvin H. Goodwin, Director of the Emory Field Station, for his very active support of the work, and to Mr. Dan J. Nelson, project leader of dove research in Georgia, for many helpful suggestions and direct aid in the field. James H. Jenkins and James C. Major helped in the coverage of piedmont areas in 1950.

Procedures

Ten study areas of 100 acres each were selected for study, five being located in Baker County on the upper coastal plain of southwest Georgia, and five in Clarke, Oconee and Madison Counties on the piedmont of northeastern Georgia. Since there was no previous experience in Georgia to indicate the proper size for a census area, 100 acres was selected as a convenient size to test. Areas were chosen with a view to sampling extensive habitat types present in the state, including

* A contribution from Pittman-Robertson Wildlife Restoration Project 17-R, and the Emory Field Station, Newton, Georgia.

what we thought might prove to be both good and poor dove breeding habitat combinations. Since large tracts in the coastal plain are not cultivated, several non-cultivated habitats were studied in that region. All the selected areas in the piedmont were farmlands since an average sample of land in this section would likely contain some acreage which was under cultivation. Habitat characteristics of the study areas are given in Table 1.

In 1950, each of the coastal plain areas was covered about once a week by Hopkins from January to September. Three of the piedmont areas were likewise covered by Odum with the aid of Jenkins and Major in 1950. In 1951,

TABLE 1.—HABITAT CHARACTERISTICS AND BREEDING DOVE POPULATION DENSITY ON STUDY AREAS

	Study Area and Habitat	Percent in Field Crops or Plowed	Edge in Miles	Peak Season Breeding Population. (No. Occupied Breeding Sites = Estimated No. Pairs per 100 Acres)		Average
				1950	1951	
C-1	Winter concentration area Farmland with dove winter food patches	11.0	1.6	6	4	5.0
C-2	Fields and fence row area Farmland without food patches	12.0	1.5	3	3	3.0
C-3	Stream-border forest Open scrub oak and flood plain forest	0.0	2.4	5	6	5.5
C-4	Mixed upland forest Scrub oak, pineland and hammock	0.0	1.5	3	3	3.0
C-5	Wiregrass longleaf pineland with patches of xeric hammock	0.0	0.9	2	2	2.0
	Powers Farms					
P-1	Diversified farmland	53.0	2.4	6	9	7.5
	Experiment Station					
P-2	Forest and cover crops	37.0	1.3	1	2	1.5
	Horticultural Farm					
P-3	Forest, orchards and vegetable crops	40.0	1.9	1	1	1.0
	Dairy Farm					
P-4	Forest, pastures and grains	35.0	1.5	–	2	2.0
	Station 10 on call count					
P-5	route—mixed farmland	59.0	1.5	–	4	4.0

Average Breeding Population: 3.3 Pairs per 100 Acres or 33 Pairs (66 Birds) per 1,000 Acre Sample.

all of the piedmont areas were jointly censused by the authors and two coverages were made of the coastal plain areas by Hopkins. Thus, two seasons' data are available, with observation more intensive on the coastal plain in 1950, and on the piedmont in 1951; one area (P-1), however, received equal attention both years. Buffer areas were also checked to reduce sampling bias, and several additional tracts were visited two or more times.

Mimeographed outline maps (Figs. 1, 3) of each of the study areas were made from aerial photographs, additional details being added from ground survey. A fresh copy was used for each regular coverage which was made between 7:00 and 11:00 a.m. On each coverage, the area was cruised systematically and doves seen and heard, and the nests found were spot-mapped with appropriate symbols indicating activities (pairs, flying, feeding, calling, etc. Fig. 1). At first the interiors of woodlands and large open fields were cruised, but it was soon found that doves in this region rarely nest far from an edge. Consequently, coverages were planned to follow, in the same manner each time, forest edges, fence rows, and other habitat junction, thus making it possible for one observer to cover 100 acres rapidly and effectively. After several coverages, occupied nesting sites generally became clearly apparent from the study of the maps, whether actual nests were always found or not. A bird or pair consistently perched, calling or otherwise associated with a potential nesting site was considered to represent a breeding pair, to be verified by location of an actual nest when possible. Groups of feeding individuals and juveniles were spot-mapped also, but were not considered as a part of the breeding population as far as that area was concerned. The spot-mapping method is illustrated in Figure 1, which shows two actual field maps based on two coverages of the same area during the height of the breeding season. On May 9, a pair flushed from nesting habitat and an additional calling bird indicated the possibility of two pairs on the west half of the area, while two nests suggested two more pairs on the east half. On June 22, an adult and two juveniles not long out of the nest, plus a nest with a pair in attendance, verified the May 9 observations on the west half, while observations on the east half also indicated two pairs. A few apparently non-breeding birds were also spot-mapped (four on May 9, for example). Thus, the estimated breeding population on this area was four pairs, with a small, variable non-breeding population.

RESULTS

Density: Breeding density ranged from one to nine pairs per hundred-acre plot (Table 1), with the average for the two-year study being 3.3 pairs per hundred acres or 33 pairs (66 doves) for the 1,000-acre cross section of Georgia country. Density on one area (P-1) was very definitely higher in 1951. Our samples were much too few to indicate whether or not there was a real difference in density between the coastal plain and the piedmont. The density on area P-5 is of special interest since one of the stations of a 20-mile call-count route was located in the center of this area. As may be seen in Figure 1, the call-count station was

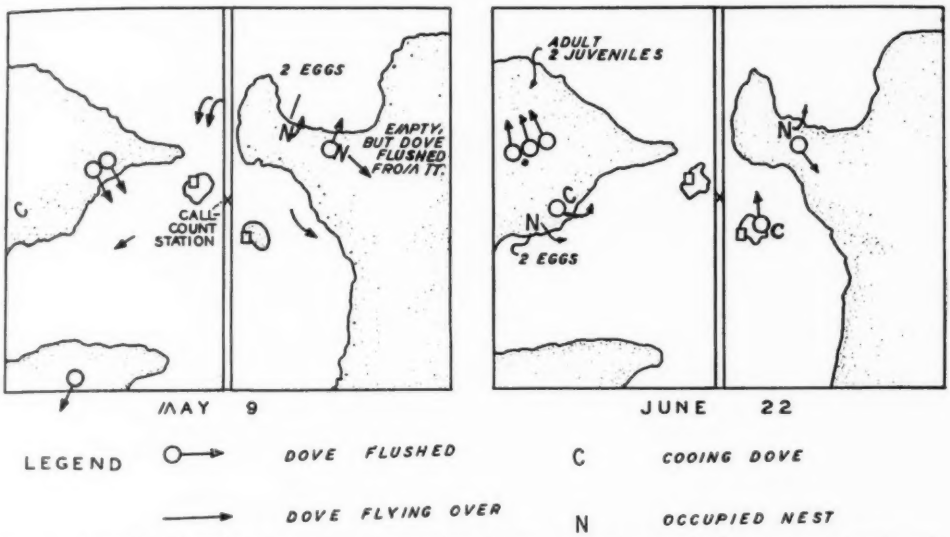

FIG. 1. Actual field maps of area P-5 illustrating the spot-mapping method of determining breeding population density.

located within easy hearing distance of the breeding sites of all four pairs nesting on the area. During May and June from one to four doves were heard calling, or an average of 2.6 per 3-minute listening stop. There were 17 such call-counts during these months made at the same time relative to sunrise (one-half hour after sunrise at this station). Thus, four pairs occupying breeding sites within easy hearing distance resulted in a call count index of 2.6 at the height of the season in this case.

Seasonal changes in populations and nesting activity. The average number of adult birds spot-mapped (seen or heard) per trip or coverage and the total number of active nests (with eggs or young) for each month in 1950 are plotted for all five of the coastal plain areas combined (500 acres) in Figure 2. The estimated breeding population level (data from Table 1) is indicated. Also plotted on Figure 2 are the monthly averages of birds (adults and juveniles) seen per trip on a 44-mile "controlled" roadside count. This count was made at the same time each week day during a drive from Camilla, Georgia, to the Field Station in the morning and from the Field Station to Camilla in the afternoon (44 miles round trip).

The number of birds observed on study areas was high during the winter due largely to the concentration of birds on plot C-1 which had winter food patches of Benne and Egyptian wheat. These food patches were plowed under in March and no concentrated food was available on the study areas for the remainder of the season. During the peak of the nesting season, April and May, slightly over half as many birds were observed per trip as were estimated as breeding. This is understandable since it is likely that one or both birds of a pair occupying a breed-

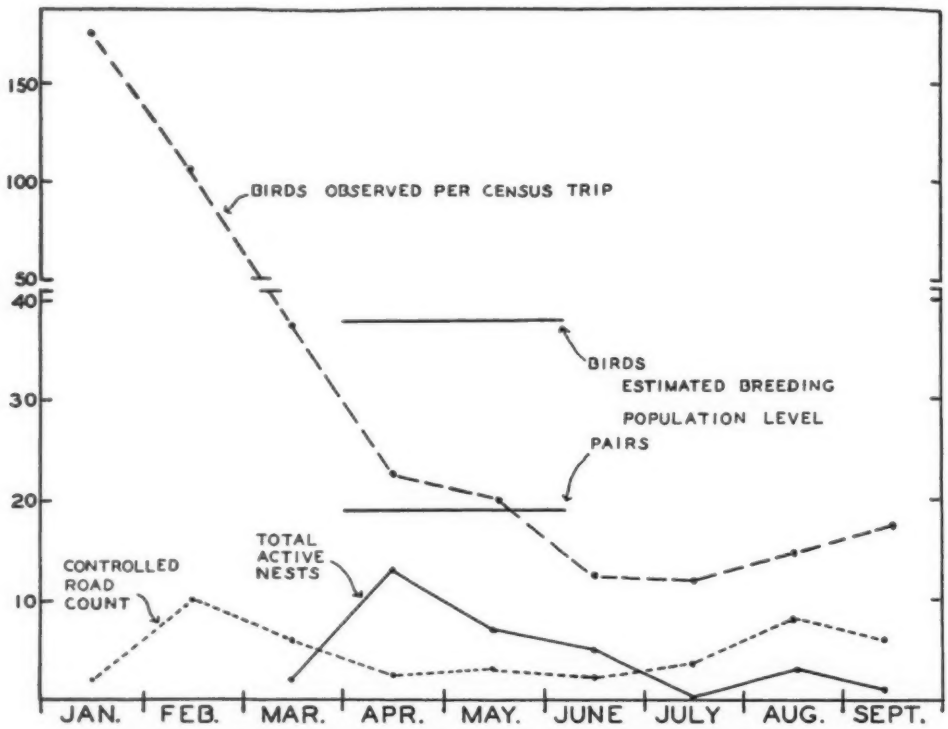

FIG. 2. Population dynamics on the coastal plain areas (500 acres) in 1950.

ing site would be absent or not observed on any one given trip. On the other hand, one area in the piedmont had concentrated food available during the spring and more birds were observed per trip than nests and other evidence indicated were breeding on the area itself. It is clear, therefore, that a simple count of the number of birds seen and heard on an 100-acre plot does not indicate the breeding population; activities of birds must be spot-mapped and established breeding sites determined for the true picture.

Although field work was begun early in January, 1950, the first nest on the coastal plain was not found until February 20; it was located on a buffer strip. The first nest on a study area was located in March on C-1. The peak of nesting activity was not the same for each individual area, but for all the areas together it was in April since the greatest number of active nests were found during this month. Doves began nesting earlier on area C-1, which had the abundant winter food, than on area C-2, which was ecologically similar but without abundant winter food. This suggests that food, along with length of day and temperature, may be critical in determining the onset of nesting.

Following the April nesting peak, there was a sharp decline during the summer (Figure 2) with a small peak in August. No new nests were found during the entire month of July (that is, nests not already with eggs or young in June)

on the study areas or buffer areas, even though as much time was spent in the field as during any other month. On the piedmont during 1950 and 1951 the nesting peak was in May and early June, and a decline in nesting during the late summer was also evident, although not so marked; some new nests were started in July as well as in August and early September.

It is important to note that the number of nests active in any one month was less than the number of breeding pairs estimated to be present; that is, not all pairs had eggs or young at any one time. For example, six pairs on area C-1 all had active nests in April, while three pairs on C-2 had only one known nest. In May there were only two active nests on C-1, while all three pairs had active nests on C-2. Thus, a nest count alone at any one time, or during any one month, would fail to indicate the maximum number of pairs.

As shown in Figure 2, the roadside count, which, of course, was independent of observations on study areas, varied inversely with nesting activity, the fewest number of birds being recorded on the roadside during the peak of nesting activity.

Breeding habitat selection. Both on the coastal plain and the piedmont of Georgia doves nested most frequently on forest edges, and especially peninsulas of forest or hedgerows which extended out into fields or other open country (Figures 1 and 3). On continuously forested areas most of the nests were located either on stream borders or at junctions between forest types. In general, population density was correlated only roughly with the linear amount of forest edge (Table 1); broad or abrupt junctions between field and forest were not as favorable as the narrow, finger-like or peninsula type of forest edge.

Doves apparently do not commonly nest in large colonies in Georgia as they do in the mid-west, lower Mississippi Valley and parts of Texas, nor do they nest in appreciable numbers in residential parts of towns as they do in the mid-west or in Florida. Dan Nelson, who has traveled widely in the state for the past two years, tells us that he has found no evidence of large breeding concentrations; nesting doves are widely scattered, as our 1,000-acre sample indicates. The agricultural campuses of Texas A. and M. and University of Georgia make an interesting contrast in this respect since apparently similar habitat is involved. Swank (1950) has reported that 648 nests were found on 81 acres in 1950, indicating a locally dense breeding population. By contrast only a few scattered pairs nest on several hundred acres of Georgia campus and farms. In the small town of Camilla on the coastal plain where Hopkins lived during 1950, few doves were seen and no nests were found. Likewise, no nests were found in 100 acres of pecan orchards, although some doves were always seen feeding among the weeds and cover crops in these orchards. The same nest was sometimes used more than once, but contrary to reports from the middle west, we never found two nests active at the same time in the same tree. Perhaps these regional differences in nesting behavior indicate that nesting sites, as such, are a limiting factor in the west but not in the southeast.

Despite the lack of nesting concentra-

tions in Georgia, the colony-nesting tendency is nevertheless evident on those of our study areas which supported the highest populations. That is, two or more pairs often nested close together and certain "traditional" spots seem to be used more frequently than other apparently similar spots. Thus, nearly half of all the nests for both 1950 and 1951 on one 100-acre farm (P-1) were built in one of the several available peninsula-like tongues of woodland, as is shown in Figure 3.

FIG. 3. Location of nests on area P-1, illustrating the choice of a peninsular type of forest edge, and the colony-nesting tendency.

Mortality. Nesting success for the study as a whole was approximately forty-eight percent, very similar to various estimates from other southern states (Quay, 1951; Moore and Pearson, 1941; Monk, 1949). Trichomoniasis was not epidemic in the study regions in 1950 and 1951. Only one positive case was found (a nestling which died in a nest in 1950).

Production of young. The productivity of those areas which were visited at frequent intervals throughout the season is shown in Table 2. The breeding population figures are the same as those in Table 1. From a study of maps it was estimated that about 10 per cent of the nests were not found. Assuming 50 per cent success of these unfound nests, the final estimate is 70 young produced by 34 pairs of doves or 2.1 young per pair, which is considered to be a low production rate.

DISCUSSION

The surprising thing about the results of this study is not the low breeding density—we had expected that—but the low production rate of only about two young per pair. This was due not to an unusually low nesting success, but

TABLE 2.—PRODUCTION OF DOVES ON STUDY AREAS

Area	Year	Peak Breeding Population in Pairs	Total Nests	Nests Probably Successful	Young Probably Produced *	Young per Pair
C-1	1950	6	9	2	4	0.7
C-2	1950	3	3	1	2	0.7
C-3	1950	5	9	6	12	2.4
C-4	1950	3	7	4	8	2.7
C-5	1950	2	2	1	2	1.0
P-1	1950	6	15	6	11	1.9
P-1	1951	9	21	12	21	2.3
Totals (actual data)		34	66	32	60	1.8
Estimated totals assuming 10% nests not found		34	73	36	70	2.1

* Some nests definitely known to have produced only one young, otherwise two young assumed.

to the fact that doves made fewer nesting attempts than expected. In the northern states doves are reported to raise at least three broods. Austin (1951) estimated that Cape Cod doves produce 4.6 young per pair. McClure (1942) reported 5-6 young per pair, in Iowa in 1938-39 but this may be high since he may have underestimated his breeding population (see Nice, 1943). Boldt and Hendrickson (1952) found that 20 pairs produced a little over 3 young per pair in a North Dakota shelterbelt area in 1950. It has often been assumed that doves in the South attempt 5 or 6 broods, and, with 50 per cent nesting mortality, they would be expected to produce at least 5 or 6 young per pair. Swank (1950) reports that doves on the Texas A. and M. campus averaged 4.4 nesting attempts which, with reported 64 per cent nesting success, would mean about 4-6 young per pair. Georgia doves in 1950 and 1951 on our widely scattered samples just did not come up to this expectation. As shown in Table 2, 34 pairs of doves attempted an estimated 73 nests, less than three nestings per pair, even assuming that a good number of nests were not found. When it is recalled that some of the areas were visited weekly and others biweekly, with a thorough search for nests, it seems that these estimates should be appreciably correct. The low natality appeared to be due to light nesting activity in February and March and especially to a sharp slump in nesting in late summer. Thus, on most areas, some time during April, May or June all pairs occupying nesting site locations had active nests; after this peak activity, however, nesting became sporadic, and on some areas it ceased altogether as far as we could observe. Since about the same number of birds were observed (Figure 2) and were heard calling throughout the season, and since buffer areas showed the same slump, neither a shifting of the breeding population nor a wholesale movement of adult birds out of the region was indicated.

The annual mortality in a population producing only two young per pair could not be over 50 per cent if the population is to hold its own. On the basis of banding, Austin (1951) calculated that juvenile doves raised on Cape Cod suffer 80 per cent mortality and adults 55 per cent, or a general population mortality of about 69 per cent per year. It is quite possible, of course, that southern doves experience a lower mortality since they are less migratory and avoid the great hazards of long migration. It is perhaps more likely that productions on our areas were abnormally low during 1950-51 and do not represent the "normal" or "healthy" population condition.

Several possibilities could be advanced to explain low productivity. Since trichomoniasis was known to have killed many doves and reduced breeding potential of others in various parts of the southeast, especially in 1950 (Haugen, 1952), it would be logical to suspect this disease as contributing to low natality. In our study areas, direct evidence was negative. Although we were on the lookout for the disease, only one case was found, a dead nestling from which trichomoniasis organisms were isolated. No sick adults were observed and Hopkins failed to find a diseased bird among 113 birds trapped and banded during late

winter and early spring on both coastal plain and piedmont study areas. It is possible, of course, that the breeding population was sufficiently weakened with chronic infections to reduce breeding activity.

Since high temperatures in summer are known to depress the breeding of birds in general, it is possible that this is a critical factor. The summer of 1950 was hot and dry. The greater summer slump in nesting in south Georgia, as compared with north Georgia, might be considered in support of such an idea. Poor production, especially in spring, might be due to food scarcity. Spring food patches or winter food patches allowed to remain might be a management possibility worth trying, since it is evident that the sooner doves start to nest, the larger the potential crop of young.

Another possibility is that dove production is density-dependent. Since doves exhibit a moderate colony-nesting tendency, they may be stimulated to nest more frequently and successfully when nearby pairs are present, especially early and late in the season when gonad activity is not at its peak and climatic conditions not optimum. If this is the case, nesting activity would be more intense with a moderately high density than with either a low density or a very high density, competition becoming a limiting factor in the latter case. The only suggestive evidence is that estimates of high nesting success and productivity have often come from the study of dense colonies, as for example, McClure's and Swank's studies previously mentioned. While the action of a density-dependent factor is only a theory, it should be tested at all opportunities. If dove nesting activity, nesting success and resultant production is density-dependent, and therefore production does vary with population density, the determination of actual density (and not just relative abundance) becomes important. Thus, a very small population might reproduce so poorly as to recover with difficulty, even with complete protection by man.

EVALUATION OF METHODS

In estimating density of breeding doves and especially in making comparisons between different regions, the degree of nesting aggregation must also be considered. Where nesting cover is scarce and nesting doves are concentrated in scattered but densely populated colonies, the large areas of intervening country obviously must be considered; in other words, the less random are the nesting sites, the larger must be the total area considered to be a sample, and greater the danger of over-estimation resulting from the study of small samples. Where nesting cover is very abundant and nesting doves relatively scattered, as in Georgia, the actual density on study areas may come closer to reflecting density over large areas. Thus, our estimate of about three plus pairs per 100 acres may be close to the actual density of doves in Georgia in 1950-51. However, this figure will remain only as an estimate until more definite figures are obtained on the actual degree of colony nesting (the non-random tendency) and until a larger number of samples can be censused. It is evident that a practicable census method must be one that can be applied to a number of samples without prohibitive expenditure of man-hours;

furthermore, the most practical method will vary with the degree of nesting aggregation.

As a result of our studies we believe that the spot-mapping method is thoroughly practicable for regions where nesting population is not concentrated in dense colonies, provided care is taken to distinguish between breeding and non-breeding birds (otherwise the large cruising radius of doves introduces errors). Thus, this method should be applicable to much of the southeast. After having covered our areas throughout the season, we found that three, or perhaps even two, coverages spaced 2 - 3 weeks apart, made at the peak of the season are sufficient for accurate estimation of population density (Figure 2). Since sketch maps may be easily and quickly made from aerial photographs available at most county court houses, only about 12 man-hours (4 hours per coverage) are needed for each 100-acre sample. It should be emphasized that the spot - mapping method is not just a nest count or a simple count of the number of birds observed, neither of which would be a good basis for an estimate in this region. If the behavior of doves in the vicinity of the nesting site is observed, it is not necessary to spend much time looking for nests. Since nesting cover is present in this region in great excess to population density, the location of nests is difficult and time-consuming; also, all pairs on an area may not have a nest active on any given day. Thus, nest counts would likely result in underestimating density. A simple count of the birds observed, we found, either results in (1) an underestimation on areas being used exclusively for nesting, since one member of a pair is likely to be off feeding and not observed, or (2) an overestimation on an area with concentrated food (grain field, for example) which attracts birds from outside the study area. Breeding sites and potential breeding pairs must be determined from spot-mapping for the true picture.

It is obvious that the spot-mapping method cannot be used in dense colonies; here the number of active nests (which are relatively easy to locate under colony conditions) can be used as a basis for estimating population density. It is also obvious that nests must be found and followed throughout the season to determine the actual production. As we have seen, even though we may know the density, or can determine it relatively easily, we cannot yet safely assume a production rate until we have more information on possible regional differences and the possible action of a density-dependent trend. Doves in the southeast have a very long potential breeding season, from January to September, and in captivity they will bring off as many as five or six broods. However, as our results clearly show, this potential or "physiological natality" is not necessarily achieved under natural conditions. Whether the "ecological natality" of doves in the southeast is low in general, or just low for the particular study period, yet remains to be seen. If limiting factors are climatic (or epidemic disease), then little probably can be done; if, on the other hand, limiting factors are related to food, habitat or to population density, then it would seem that much could be done to increase the productivity of breeding doves in the southeast.

SUMMARY

1. The spot-mapping method was tested and the population density of breeding doves determined on ten 100-acre study areas, five located on the coastal plain and five on the piedmont of Georgia, during the 1950 and 1951 seasons. Natality and the total production of juveniles were determined on six of the areas.

2. Breeding density at the peak of the season (April-May for the coastal plain, and May-June for the piedmont) varied from one to nine pairs per 100-acre plot with an average of 3.3 pairs per 100 acres, or a total of 33 pairs (66 doves) for the 1,000-acre sample (Table 1) which included a variety of habitat combinations widespread in Georgia, namely, farms of various types, bottomland tracts, upland forest, and areas with and without winter food and large winter flocks. Four pairs nesting within easy hearing distance resulted in a May-June average call-count index of 2.6.

3. Breeding density seemed best correlated with the amount of available peninsula or "double" forest edge on farms (Figure 3) and the extent of habitat junctions on forested areas. Most areas were occupied largely by nesting birds between April and July. Some had a variable number of visitors depending on the presence of concentrated food supplies.

4. In Georgia as a whole, breeding doves are relatively scattered, no densely populated nesting areas or colonies having been found or reported. Residential areas in towns, the University campus and pecan or peach orchards were relatively little used as nesting habitat in contrast to reports from northern and western regions. However, a definite colony nesting tendency was evident on those of our study areas which had the highest density, since several pairs often occupied nesting sites close together (but rarely in the same tree) (Figure 3).

5. Production of young was very low, being estimated at only 2.1 birds per pair for 33 pairs on the 700 acres on which an attempt was made to find all the nests and follow their history. Low production was not due to unusually high mortality (nesting success 48 per cent—close to average reported in many other studies) but to low natality resulting from an average small number of nesting attempts per pair. Nesting activity was light in the early spring and slumped sharply in mid-summer, especially in the coastal plain. Disease, high mid-summer temperatures, low food supply and the action of a possible density-dependent effect are suggested as possible explanations for low production.

6. The spot-mapping method was judged to be an effective and practicable census method in regions where the breeding population is scattered and not concentrated in dense colonies, provided dove activities are carefully spot-mapped and nesting sites ("territories") determined in order to distinguish between breeding and non-breeding birds. Three visits spaced 2 - 3 weeks apart at the peak of the season will give a reliable estimate of the breeding density. Assuming maps may be quickly made from aerial photos, this amounts to about 12 man-hours per 100-acre sample area. In Georgia, a nest count alone is not a reliable means of determining

density unless made with a large expenditure of time, since nesting cover is very abundant in proportion to the population level and scattered nests, therefore, often difficult to locate. Likewise, a simple count of birds observed on a 100-acre area is not a good measure of breeding density because of the large home range of the dove. Determining actual production is a more difficult and time-consuming problem than simply determining density. A production rate cannot be assumed until more is known about regional, local (food), and density-dependent effects on natality.

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Accepted for publication May 25, 1952.

FISH LOSS AND MOVEMENT IN IRRIGATION DIVERSIONS FROM THE WEST GALLATIN RIVER, MONTANA *

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Introduction

Fish loss in irrigation diversions in Montana was a management issue even before the turn of the century. An attempt was made to prevent fish loss as early as 1893 when legislation was passed requiring screens to be placed in ditches from September 1 to March 1, during the period of little or no water use. The law obviously had no practical value and was repealed in 1897. No further legislation concerning screens has been enacted since that time.

An early typical account placed the loss of fish in the thousands for a single canal (Montana Fish and Game Department, 1904). Periodic pleas for control measures stimulated investigations of screening devices by the State Fish and Game Department. A few of the experimental installations were considered successful, but in 1942 the Department reported that annual maintenance for a statewide screening program would cost three times as much money as was available for the operations of the entire Fisheries Division (Montana Fish and Game Department, 1942). While past work in Montana was directed toward control, little quantitative information has been secured on the actual loss or the factors affecting it. Answers to inquiries indicate the same unsolved problem exists in other western states and provinces of Canada having a serious loss of non-migratory fish in irrigation diversions.

Data for the present study of fish loss and movement in irrigation diversions were collected during the 1950 and 1951 irrigation seasons (June to October). Observations were confined to the diversions of the West Gallatin River, Gallatin County, Montana.

* Contribution from Montana State College, Agricultural Experiment Station, Project No. MS 844, Paper Number 277 Journal Series, and the Fish Restoration Division, Project F-3-R, Montana Fish and Game Department.

Acknowledgements

The writer extends thanks to Dr. C. J. D. Brown who directed the research and assisted in preparing the manuscript. The Montana Fish and Game Department furnished considerable time of field personnel, gave financial assistance and contributed weir materials. Mr. John Spindler and Mr. George Holton gave valuable field assistance. The help of Mr. Bill Papke, River Commissioner, in securing information on the various canals is gratefully appreciated. Thanks are also due the United States Fish and Wildlife Service, Missouri River Basin Studies, and the farmers and ranchers of Gallatin Valley for their cooperation.

Description of the West Gallatin River in the Study Area

The section of the West Gallatin River under observation (approximately

20 miles) extends from near the mouth of Gallatin Canyon to 1300 feet downstream from Irwin Bridge. The stream emerges from the canyon at about 5000 feet elevation and flows north through the west side of Gallatin Valley. Its gradient is approximately 34 feet per mile. Maximum channel width is 150 feet, and the average is near 70 feet. In several places the stream flow is divided into two or more channels as it passes through the relatively narrow flood plain (approximately 200 to 500 yards wide). Pools are slightly less abundant than riffles. Bottom materials are predominantly rubble and gravel and stream banks are generously covered by shrubs and cottonwood trees. Trout production is good. Intensive creel census in the study area disclosed an average catch per fisherman hour of 0.57 (0.36 of a pound) in 1949 and 0.51 (0.35 of a pound) in 1950 (Missouri River Basin Studies, 1951).

A total of 52 diversion canals originate within the study section. They range in size from 1 to 268 second-feet (decreed right) and irrigate approximately 90,000 acres. None of the diversions is screened. Each year some of the West Gallatin River below Irwin Bridge is subject to varying degrees of drying-up from dewatering practices. Pools become warm and stagnant and it is not unusual for many fish to die. In 1950 about 2 miles of the West Gallatin River in this area was lost due to dewatering. The average diverted flow of 822 second-feet (discounting return flows) varied from 1620 on June 5, to 387 on September 15. From 1930 to 1945 the average annual river flow was 682 second-feet. A minimum annual flow of 533 second-feet was recorded for the water year (October 1 to September 30) 1940-41, and a maximum annual flow of 956 second-feet occurred during the water year 1947-48 (Missouri River Basin Studies, 1951).

Species of fish found in the study area were rainbow trout (*Salmo gairdneri*), brown trout (*Salmo trutta*), cutthroat trout (*Salmo clarki*), eastern brook trout (*Salvelinus fontinalis*), mountain whitefish (*Prosopium williamsoni*), longnose sucker (*Catostomus catostomus*), white sucker (*Catostomus commersoni*), sculpin (*Cottus bairdi punctulatus*), and longnose dace (*Rhinichthys cataractae*). Numerous rainbow-cutthroat hybrids were present, but for purposes of this study they were classified as rainbow or cutthroat, depending on which trait was dominant.

FISH MOVEMENT IN IRRIGATION CANALS

A two-way fish weir, modified from a design described by Shetter (1938), was installed in the Keughen Canal in the spring of 1950 and another of similar design was placed in the Low Line Canal in the spring of 1951 for the purpose of securing information on the effect of water temperature and fluctuation on daily and seasonal movement of fish. The intakes of these two canals are approximately one-quarter mile apart on the same side of the river (Fig. 1). The Keughen Canal is of medium size (70.3 c.f.s.) and the Low Line (147.5 c.f.s.) is large in comparison with other canals of the area. Each of these ditches had a reputation for taking many fish. An effort was made to prevent fish loss in the Keughen Canal by local sportsmen in 1935. They installed a stationary-bar type screen with a paddle wheel

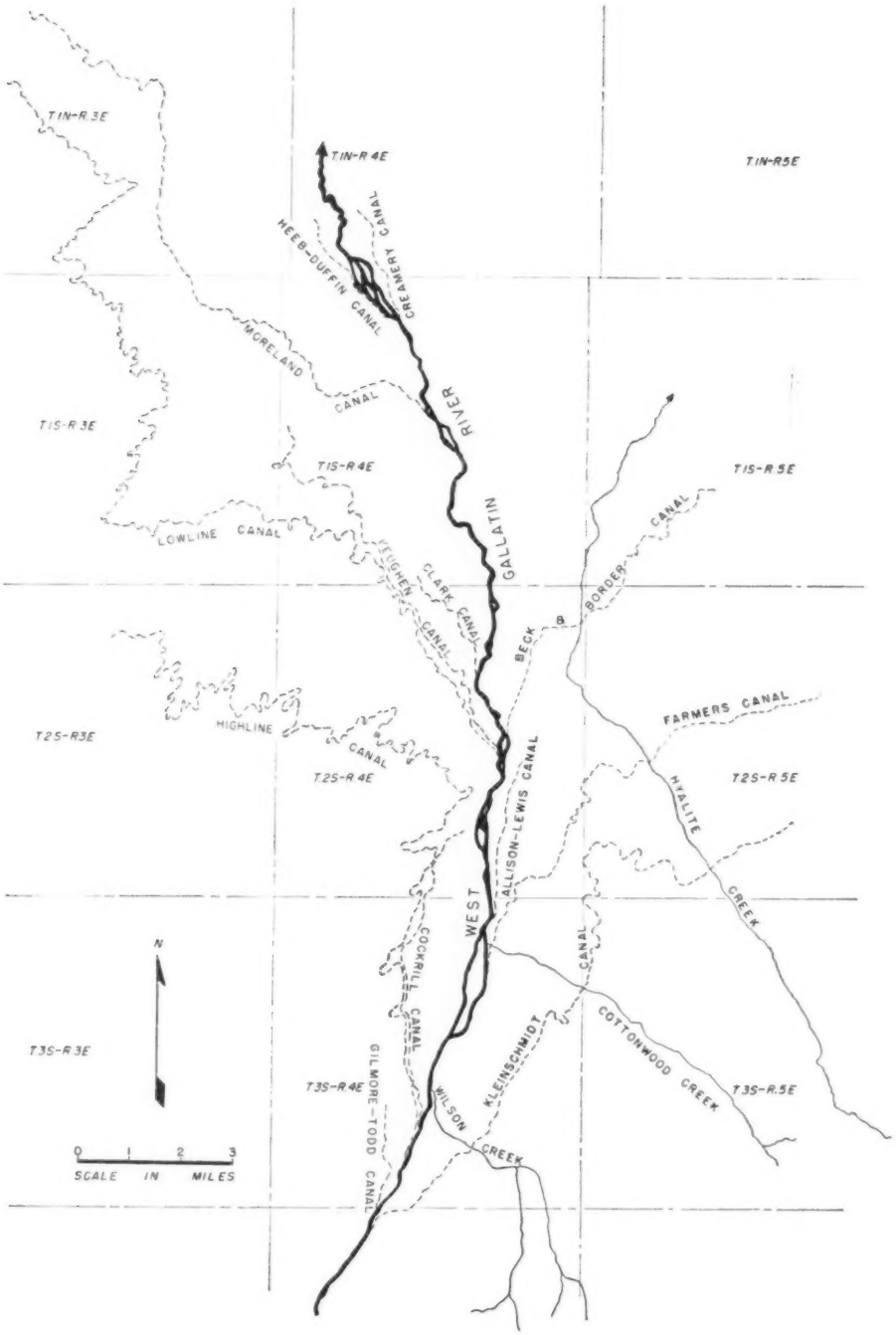

FIG. 1. A 20-mile section of the West Gallatin River showing the 13 canals studied.

scraper, but this device required so much maintenance that it was removed in 1936.

The Keughen Canal fish weir was placed 200 feet behind the headgate in order not to retard the flow at the intake. The main arm of the weir consisted of a grid with ½-inch openings. This was effective in excluding fish over 5 inches in total length. The Low Line Canal fish weir was placed 160 feet behind the headgate, and its grid had openings of ½ to ¾ inches. This spacing stopped most of the fish over 7 inches in total length.

The fish captured each day were weighed to the nearest 0.01 of a pound, and their total lengths were taken to the nearest 0.1 of an inch. Each fish was fin clipped and allowed to continue in the direction it was going when caught.

Determination of fish loss for whole irrigation seasons was not possible because debris carried by spring run-off delayed weir operations 4 to 7 weeks, and operations had to be discontinued about 4 weeks early each fall because of leaves. The Keughen weir was operated 61 days in 1950—July 27 to September 26, and 84 days in 1951—June 28 to September 19. The Low Line installation was maintained 41 days from July 18 until the canal was turned off August 27, 1951.

Daily maximum and minimum water temperatures were taken at the Keughen fish weir. The water temperatures at this station were identical with those taken at the Low Line weir and in the river at the canal intakes. Canal water levels were recorded daily. A gage was maintained during the 1951 season in the West Gallatin River near the weir sites.

INITIAL MOVEMENT

Two groups of fish are considered in relation to movement—those which were already in the canal when the trap was installed (up-canal migrants) and those which came down the canal subsequent to its installation (down-canal migrants). The total number of initial down- and up-canal migrants during the 61-day trap operation in 1950 was 824. During the 84-day period of 1951, 899 fish showed initial movement in Keughen Canal (Table 1). There were 24 down-canal trout migrants taken the first season, and 14 or 58.3% of these were cutthroat. Cutthroat comprised less than 2% of all trout recorded in the 1950 creel census for the adjacent section of the West Gallatin River (Missouri River Basin Studies, 1951). In the second season 38 trout moved down the canal with brook trout and rainbow trout predominating. There were only 5 up-canal trout migrants in 1950 as compared to 17 in 1951. Every trout species was represented in this up-canal movement except cutthroat. Trout comprised 3.5% of the total initial movement the first year and 6.1% the second year.

Whitefish and sculpins were also taken more frequently the second year; suckers and dace less frequently. Suckers showed a greater movement than any other species. About 1% of these were white suckers and the rest were longnose.

Only a few large fish were taken in the Keughen Canal (Table 1). One brown trout in 1950 and 2 in 1951 were over 17 inches in total length. Six of the whitefish captured exceeded 10 inches in total length. There were a few suckers

TABLE 1.—INITIAL FISH MOVEMENT IN THE KEUGHEN CANAL

Species	Movement down	Movement up	Percentage movement down	Percentage movement up	Percentage movement total	Length in inches (total movement) average	Length in inches (total movement) range
July 27 to September 26, 1950							
Rainbow	5	0	1.0	0.0	0.6	6.2	4.6– 8.4
Cutthroat	14	0	2.8	0.0	1.7	7.8	5.9–10.0
Brook	3	3	0.6	0.9	0.7	7.0	2.5– 8.4
Brown	2	2	0.4	0.6	0.5	...	2.6–18.7
Whitefish	33	4	6.6	1.3	4.5	4.2	2.6–13.7
Suckers	209	165	41.6	51.3	45.4	5.3	2.6–17.7
Sculpins	156	108	31.1	33.5	32.0	3.1	2.0– 5.0
Dace	80	40	15.9	12.4	14.6	3.8	2.4– 5.8
Total	502	322	100.0	100.0	100.0		
June 28 to September 19, 1951							
Rainbow	12	7	2.2	2.0	2.1	5.7	2.4–14.5
Cutthroat	5	0	0.9	0.0	0.6	8.5	5.9–11.0
Brook	13	5	2.4	1.4	2.0	5.1	2.4– 9.6
Brown	8	5	1.5	1.4	1.4	6.5	2.7–18.3
Whitefish	63	14	11.5	4.0	8.6	3.8	2.5–12.3
Suckers	211	127	38.6	36.0	37.6	5.9	2.3–17.4
Sculpins	142	171	26.0	48.4	34.8	3.3	2.0– 5.1
Dace	92	24	16.9	6.8	12.9	3.9	2.5– 6.2
Total	546	353	100.0	100.0	100.0		

of intermediate size (9 to 16 inches), but most of the specimens taken were less than 9 inches in length.

Initial movement in the Low Line Canal during the 41 days of observation in 1951 was greater in the up-canal direction for all species except cutthroat trout and suckers (Table 2). Of the total 197 initial migrants, 52.3% were trout and whitefish, and 47.7% were suckers, dace, and sculpins. Only 10 trout moved down the canal compared to an initial up-canal movement of 67. Suckers again showed more initial movement than any other species.

The two largest trout taken in the Low Line Canal included a brown trout (20 inches, 3.53 pounds) and a rainbow trout (18.5 inches, 2.02 pounds). An additional 6 trout and 5 whitefish

TABLE 2.—INITIAL FISH MOVEMENT IN THE LOW LINE CANAL, JULY 18 TO AUGUST 27, 1951

Species	Movement down	Movement up	Percentage movement down	Percentage movement up	Percentage movement total	Length in inches (total movement) average	Length in inches (total movement) range
Rainbow	1	33	1.5	25.0	17.3	11.3	7.0–18.5
Cutthroat	4	1	6.2	0.8	2.5	7.3	5.1– 8.6
Brook	0	9	0.0	6.8	4.6	9.5	5.5–12.9
Brown	5	24	7.7	18.2	14.7	10.2	6.9–20.0
Whitefish	9	17	13.8	12.9	13.2	10.8	4.0–15.9
Suckers	37	25	56.9	18.9	31.5	7.9	5.9–18.2
Sculpins	7	13	10.8	9.8	10.1	3.6	3.0– 4.3
Dace	2	10	3.1	7.6	6.1	5.3	4.7– 5.7
Total	65	132	100.0	100.0	100.0		

exceeded one pound each. The largest whitefish was 1.70 pounds. Only one sucker larger than 9.7 inches was taken.

RANDOM MOVEMENT

In 1950 all down-canal migrant trout in the Keughen Canal remained down, and all but one (brook trout) of the up-canal migrants remained up. Of the trout captured in this ditch the second year, one down-canal rainbow and one down-canal brook trout migrant came back up and returned down a second time. One up-canal migrant from each of these two species returned down. None of the 1951 down-canal brown trout migrants returned to the river, but one up-canal migrant went back down and stayed.

There was no random whitefish movement observed the first year, but in 1951, 3 down-canal whitefish migrants circled back and down the canal a second time. Three of the up-canal whitefish migrants went back down and stayed.

There were 4 down-canal migrant suckers in 1950 that came back up and then moved down a second time, while 103 of the up-canal sucker migrants went back down. Six of these moved up the canal a second time but only one of them stayed. A total of 19 down-canal sucker migrants in 1951 moved back up only to return down a second time, and 2 of these came back up again and returned down a third time. The number of up-canal sucker migrants that went back down the second year was 105, and of these 3 came up and returned down again.

Only one down-canal sculpin migrant moved back up and then down the canal during the first season. A total of 21 up-canal migrants of this species went back down, and 3 of these came back out and stayed. Five of the down-canal migrants the second year returned back out of the canal. There were 28 up-canal migrants which returned down. Two of these made a second round trip through the traps.

Of the dace that were observed to move down the Keughen Canal in 1950, 6 made a complete circle back through the traps. Eight of the up-canal migrants moved back down, and one of these moved up and returned down the canal a second time. There were 17 down-canal dace migrants in 1951 that moved up and then returned down the canal. Four of these made still another round trip through the traps. Only 5 of the up-canal migrants showed random movement back down the canal. One of these moved up a second time and stayed.

Of all initial down-canal migrants in the Low Line Canal, one brown trout and 7 suckers came back up and stayed. The up-canal migrants which returned back down the canal included one each of rainbow trout, brown trout, and whitefish. The brown trout came back up a second time and stayed.

MOVEMENT IN RELATION TO TEMPERATURE AND WATER LEVELS

The most concentrated down-canal movement of trout and whitefish in the Keughen Canal occurred both years during the third week in September. Mean weekly water temperatures for these periods (48.4° and 49.1°F) were the lowest reached while the trap was in operation. The temperature decline in each case was associated with rainy weather. Huntsman (1945) described

freshets as a stimulant to the movement of certain salmonids and other fish. During the period August 2-8, 1951, twice as many trout and whitefish (14) moved down the Keughen Canal as were captured in the previous 5 weeks. This increased movement followed a day of heavy precipitation (0.99 of an inch). However, there was no marked increase in trout or whitefish movement following 2 days of rain of moderate intensity (0.54 and 0.58 of an inch) which occurred 3 weeks later.

The 59 suckers that moved up the Keughen Canal during the first 5 weeks of trap operation (July 27 to August 30) in 1950 was about twice the down-canal number. Down-canal sucker migrants for the week August 31 to September 6 totaled 95, which was 5 times greater than for any previous week. Up-canal numbers increased, but to a lesser degree. The mean water temperature this week (58.7°F) was the highest recorded for the entire study period. Sucker movement in the second year could not be correlated with warm or cool periods.

More suckers moved down the canal during the day than at night in the week of highest mean water temperature. There were 50 day-time migrants as compared to 23 night migrants in a 3-day period. No day-time up-canal movement occurred on these days. With the exception of this period, only an occasional fish of any species was taken in the traps during the daytime.

Sculpin movement increased both seasons after the end of August. Minimum dace movement coincided with low water temperatures. Those taken between June 28 and July 21 carried spawning colors and several were ripe.

Fish movements in the Keughen Canal were not observed to be affected by water reductions, but in the Low Line Canal a direct correlation existed between severe water fluctuations and trout movement upstream (Fig. 2). A total of 43 trout moved into the up-canal trap in the 3 days following a water reduction of 41 c.f.s. (August 2). The volume of flow was decreased to about one-quarter of the canal capacity at this time. On August 16 the flow was reduced by 39 c.f.s., and 13 more trout moved up the canal. Only 3 trout moved up following the last reduction (49 c.f.s.) on August 24. The 59 trout which came out following these reductions constituted 88% of all up-canal migrant trout for the season. Trout size as well as numbers decreased with each succeeding cut in water volume. Their average weight for the 3 reductions beginning with the first was 0.66, 0.53 and 0.19 pounds.

The river water level near the weir sites underwent a natural drop of 3.5 inches during the 1951 observation period. This shrinkage did not cause a measurable fish movement out of the river into the canals.

FISH LOSS IN IRRIGATION CANALS

Fish loss was investigated in 13 of the 52 irrigation canals in the study area (Fig. 1). Loss through the Keughen and Low Line weirs was established by actual counts. Shocking supplemented by poisoning and general observations was employed in all 13 canals, including the 2 with weirs. Intensive sampling began in mid-July, 1951, after the volume of flow in the canals was reduced to decreed right. These reductions amounted to about one-half of the canal

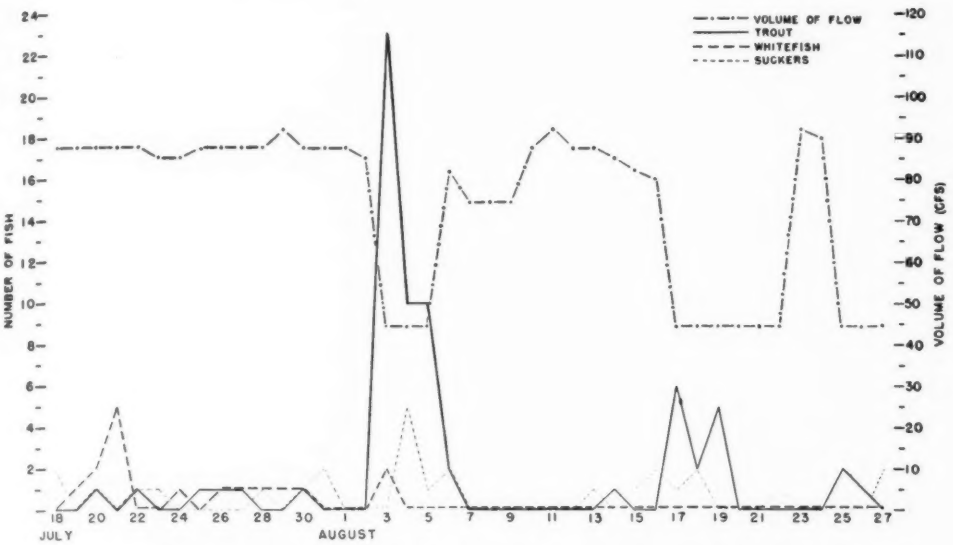

FIG. 2. Movement of trout, whitefish and suckers up the Low Line Canal following water reductions.

capacity in some instances. It was impractical to attempt sampling earlier in the season when the canal banks were full. The fish, therefore, had an opportunity to enter the canals approximately one month before sampling began. Samples were taken later in the season in 6 canals after they were turned off.

A 125-volt, 250-watt direct-current generator was generally used for shocking, but on 5 occasions a 240-volt, 500-watt alternating-current machine was employed. Holton (1952) found the direct-current generator 97% efficient in taking fish 3.5 inches and longer in total length from a spring-fed creek in the area (maximum flow 14.7 c.f.s.). In irrigation ditches this equipment was not always effective in taking fish less than 7 inches in length. It was not used in the larger ditches when they were carrying a head of water. The difference in efficiency between ditches was undoubtedly due to their highly variable widths, depths, and velocities. Sections sampled were usually 300 feet in length for active canals. Each section was blocked at the end with nets and shocked until no more game fish could be taken. In canals which were turned off (inactive), section lengths varied from 110 to 7,260 feet. Derris root (rotenone) was used to determine fish losses in parts of the High Line and Gilmore-Todd Canals following headgate closure.

One section was established near the headgate on each canal studied. Other sample areas were chosen to represent all regions of a canal as far as accessibility would permit. Unbiased selection at each point of access was striven for by sampling the first portion of the canal approached. Some spot sampling was done in areas likely to have concentrations of game fish. All sections except those of inactive canals containing clear,

shallow water were sampled by shocking. Derris root was employed in the shallow areas where a slight current existed. Other shallow (or dry) sections were carefully canvassed. Of the total footage covered in the canals which were turned off, shocking comprised 53.4%, poisoning 28.5% and canvassing 18.1%. Six 300-foot stratified random sections were established by random numbers (Snedecor, 1946) in the Farmers Canal at a time when it carried 37.5 c.f.s. of water. These were in addition to two sections (not random) selected in the upper one mile of the canal.

All trout and whitefish captured were counted, weighed and measured. Sculpins, dace and suckers were counted, but only a representative sample was weighed.

Loss Determined by Weirs

The fish loss determined by means of the weirs does not include spring and fall segments of the irrigation seasons when debris-laden water prevented trap operation. Net loss (numbers and pounds) for each trap operation period is the total permanent up-canal numbers of the various fish species less their total initial down-canal numbers. Net gain is given in numbers and pounds when more fish came out than went down through the weirs.

There was a net loss of 20 trout (5.56 pounds) through the Keughen Canal weir in 1950 and 24 trout (3.50 pounds) in 1951 (Table 3). Whitefish comprised 9.4% of the total net number lost the first year (11.4% of the poundage) compared to 15.5% the second year (4.1% of the poundage).

TABLE 3.—FISH LOSS IN THE KEUGHEN CANAL AS DETERMINED BY WEIR

Species	Down (loss)		Up (gain)		Net loss	
	number	weight (pounds)	number	weight (pounds)	number	weight (pounds)
July 27 to September 16, 1950						
Rainbow	5	0.45	0	0.00	5	0.45
Cutthroat	14	2.16	0	0.00	14	2.16
Brook	3	0.53	2	0.20	1	0.33
Brown	2	2.64	2	0.02	0	2.62
Whitefish	33	3.23	4	0.04	29	3.19
Suckers	209	19.83	63	2.78	146	17.05
Sculpins	156	2.16	90	1.08	66	1.08
Dace	80	1.57	32	0.57	48	1.00
Total	502	32.57	193	4.69	309	27.88
June 28 to September 19, 1951						
Rainbow	12	1.86	6	0.05	6	1.81
Cutthroat	5	1.17	0	0.00	5	1.17
Brook	13	1.36	4	0.04	9	1.32
Brown	8	1.83	4	2.63	4	(0.80)
Whitefish	63	1.45	11	0.48	52	0.97
Suckers	211	18.86	22	2.04	189	16.82
Sculpins	142	2.46	148	2.15	(6)	0.31
Dace	92	2.61	20	0.52	72	2.09
Total	546	31.60	215	7.91	331	23.69

Non-game species made up 84.1% of the number and 68.6% of the weight loss in 1950, and 77.4% of the number and 77.9% of the weight in 1951. A net gain of 57 trout (38.10 pounds) and 7 whitefish (8.51 pounds) returned to the river from the Low Line Canal during the season (Table 4). There was a net loss of 5 suckers (0.09 of a pound) through the Low Line weir.

LOSS DETERMINED BY SAMPLING THE CANALS

There is a great deal of diversity in the physical characteristics of the canals studied and in the numbers of fish each attracted. This was recognized by Wales (1948) who reported that some canals take few non-migratory trout. The immediate area behind canal headgates is characterized by maximum flow, clear water, and often pools. Progressing down the canals, flow is reduced by withdrawal for irrigation and turbidities generally increase as a result of return flow and other factors. The greatest number of fish was found in the upper one-quarter to one-half mile of canal except in three ditches where fish concentrations were associated with spring-fed areas or creeks entering the channel. A few canals have two headgates—one at the point of diversion from the river and the other some distance down the canal. The downstream headgate is used to regulate the flow into the canal proper. Here surplus water is by-passed back to the river. Water was permitted to flow all year in the area between the two headgates of the Low Line Canal, but in the Keughen and High Line Canals this area is mostly dry after the canals are turned off in the fall. Seepage from springs maintains a small flow between the two headgates of the Farmers Canal after it is turned off.

The area between the headgates was shocked after headgate closure in the Keughen Canal in 1950 and Farmers Canal in 1951. There were 71 trout (12.31 pounds) and 22 whitefish (0.94 of a pound) taken from the 400-foot section of the Keughen Canal. These fish comprised 73.2% of the number and 72.2% of the weight of all trout and whitefish captured in the entire canal, exclusive of weirs. Two 300-foot sections of the most favorable habitat between headgates in the Farmers

TABLE 4.—FISH LOSS IN THE LOW LINE CANAL, JULY 18 TO AUGUST 27, 1951, AS DETERMINED BY WEIR

Species	Down (loss)		Up (gain)		Net	
	number	weight (pounds)	number	weight (pounds)	number	weight (pounds)
Rainbow	1	0.12	32	19.60	31+	19.48+
Cutthroat	4	0.49	1	0.20	3−	0.29−
Brook	0	0.00	9	3.36	9+	3.36+
Brown	5	0.75	25	16.30	20+	15.55+
Whitefish	9	3.31	16	11.82	7+	8.51+
Suckers	37	6.97	32	6.88	5−	0.09−
Sculpins	7	0.16	13	0.22	6+	0.06+
Dace	2	0.09	10	0.43	8+	0.34+
Total	65	11.89	138	58.81	73+	46.92+

Canal were sampled. This represented approximately one-fifth of the area. The 504 trout (88.4 pounds) and 120 whitefish (2.6 pounds) captured made up 92.9% of the total number and 84.7% of the weight of all game fish taken in the canal.

Fish observed in the Low Line Canal after it was turned off were predominantly small. Apparently most of the large trout had moved out through the weir during earlier water reductions. In the 5,165 feet sampled, only 21 trout ranging from 7 to 13 inches were taken. The average length for the 405 trout captured was 3.4 inches. All whitefish were less than 5 inches in length. Approximately 1640 lineal feet of canal was shocked in the first one-half mile behind the headgate. About 96% of the trout and whitefish were taken in this area, which was characterized by a series of pools.

Considerable variation was shown between the years of 1950 and 1951 in the pounds of game fish taken from the High Line Canal (Table 5). Sampling the first year was limited to one 1245-foot section immediately behind the down-canal headgate. This area yielded 18 trout (13.7 pounds) and 90 whitefish (2.6 pounds). Only 9 trout (1.94 pounds) and 6 whitefish (1.60 pounds) were taken in over 2 miles of sections sampled in 1951. Although there were just two 300-foot sections shocked immediately behind the headgate the second year, it is probable that the variation was due to headgate manipulation. In 1950 the headgate was closed tightly without giving fish an opportunity to return to the river after they had been stimulated by reduced flow, whereas in 1951 flow had been reduced to approximately 7 c.f.s. a few days before shocking.

Few game fish were found in the Gilmore-Todd and Cockrill Ditches (Table 5). They were the smallest ditches sampled. A total of 4800 feet of the Gilmore-Todd Ditch adjacent and downstream from the headgate was

TABLE 5.—CANALS SAMPLED, NUMBERS AND WEIGHTS OF GAME FISH CAPTURED, AND ESTIMATED NUMBERS AND WEIGHTS OF LEGAL GAME FISH

Name of canal	Flow decreed right (c.f.s.)	Length of canal (miles)	Month and year sampled	Number of sections sampled	Percentage of length sampled	Footage covered			Game fish captured				Estimated legal game fish loss	
						Shocker	Poison	Canvassing	Trout		Whitefish			
									No.	Lb.	No.	Lb.	No.	Lb.
Farmers	268.0	10.4	8–9/51	16	9.0	4,140		1,000	547	104.66	125	2.76	537	242
Kleinschmidt	151.0	19.0	9/51	10	5.5	3,428		2,110	305	103.36	185	3.74	560	277
High Line	147.5	30.3	9/50	1	0.8	1,245			18	13.78	90	2.60		
			8/51	13	6.8	2,876	6,060	1,885	9	1.94	6	1.60	61	23
Low Line	147.5	31.6	8/51	7	3.1	3,265		1,900	405	12.11	462	9.21	132	71
Keughen	70.3	9.9	8–9/50	6	4.4	2,310			89	14.90	38	3.44	167	44
			7/51	3	2.2	1,160			9	1.94	6	2.74		
Beck and Border	50.0	7.6	8–9/51	8	24.0	9,610			235	93.13	22	1.27	368	176
Moreland	48.0	14.4	7/51	3	1.5	1,160			9	6.96	8	5.97		
Heeb-Duffin	....	....	7/51	4	....	705			61	26.10	25	2.71		
Creamery	20.0	2.5	7/51	3	8.7	1,150			8	2.95	1	0.10	44	33
Allison-Lewis	18.0	3.3	9/51	6	10.3	1,800			145	28.95	0	0.00	851	289
Clark	16.0	3.7	9/51	3	5.6	1,100			126	10.30	0	0.00	77	20
Gilmore-Todd	14.9	2.0	7/51	1	45.5		4,800		12	2.60	41	0.21	22	6
Cockrill	5.9	7.2	8/51	6	4.7	1,800			11	2.21	13	0.26	16	5
Total				90		35,749	10,860	6,895	1989	425.89	1022	36.31	2835	1186

poisoned. The trout and whitefish taken from this area were widely distributed. There were six 300-foot sections shocked in the Cockrill Ditch, and only a few fingerling whitefish were found beyond the first one-quarter mile below the headgate. The largest trout taken from either ditch was an 11-inch rainbow.

Creeks entered 3 of the canals studied (Fig. 1). In these instances water was usually released from the canal opposite the point of creek entrance in order to maintain a flow in the creek below. Brook trout were dominant and often abundant in the canals near creeks. The average length of all brook trout taken in the vicinity of creeks was over 9 inches. One brook trout measured 18.2 inches in length and weighed 3.02 pounds. The greatest concentrations of brook trout in the canals were found during the spawning season. On September 29 in the Kleinschmidt Canal, 138 brook trout (54.61 pounds) were found in a 320-foot section around the entrance point of Wilson Creek. In the same canal and on the same date 66 brook trout and one rainbow trout (total weight 35.67 pounds) were taken from a 252-foot section located approximately 3.5 miles below the place where Cottonwood Creek enters the canal. The Beck and Border Canal, which is bisected by and receives much of its water from Hyalite Creek, contained 192 trout (80.3 pounds) in a 7260-foot section beginning approximately 2 miles below the place of bisection. These fish had entered the canal before September 23 and were blocked by an 8-foot falls from returning to the creek. Species composition consisted of 147 brook trout (55.78 pounds), 36 rainbow trout (19.60 pounds), 8 brown trout (4.48 pounds), 1 cutthroat trout (0.44 of a pound), and 6 whitefish (0.93 of a pound). A few brook trout were disbursed around Hyalite Creek in the Farmers Canal up to August 30 when the last samples were taken. No brook trout, or any game fish for that matter, were found in the lower one-half of any large canal not modified by a creek. One 16.1-inch whitefish moved down the High Line Canal for a distance of approximately 15 miles.

The water in spring-fed ditches during the non-irrigation season is usually lost through seepage after flowing a short distance. However, it may, as observed in the Allison-Lewis Ditch, maintain a small flow in most of the channel all year. Six 300-foot sections of this ditch were shocked in mid-September. The headgate was open at the time to allow a flow of 6.9 c.f.s. A total of 145 trout, including 128 brook trout (24.89 pounds), 10 brown trout (1.43 pounds) and 7 rainbow trout (2.63 pounds), were taken. Trout less than 7 inches made up 43.4% of the total number. There were 66.4 pounds of trout per acre for the combined 6 sections. Three fingerling whitefish were captured.

The Heeb-Duffin and Creamery Ditches are located near the dewatered portion of the West Gallatin River (Fig. 1). There is no headgate on the Heeb-Duffin Ditch and flow into its intake ceases when the river reaches a low level. Water from another ditch enters the Heeb-Duffin 500 feet behind its intake, thus maintaining flow over much of its course for a longer period. An isolated 350-foot pool near the intake was shocked July 12. A total of 41 trout weighing 20.46 pounds was taken. Of these, 34 were brown trout, 4 were rainbow trout, and 3 were brook

trout. Six whitefish weighing 1.80 pounds were also captured. The Creamery Ditch had a flow of 20 c.f.s. at the time of sampling on July 19-20. This was almost one-half of the remaining river flow. Three sections were shocked (1150 feet) and these yielded 6 brown trout, 2 rainbow trout, and a 7-inch whitefish for a total weight of 3.05 pounds.

Several irrigated fields were inspected for stranded fish, but none was found. Many of the farmers in the area irrigated by the Gallatin canals were interviewed in both 1950 and 1951. They reported very little or no game fish movement into fields.

The species composition of all 1882 trout taken by sampling in 1951 was 46.1% brook trout, 37.6% brown trout, 16.2% rainbow trout, and 0.1% cutthroat trout. Fingerling trout comprised 54.7% of the total number. About 97.7% of the 894 whitefish were fingerlings. There was a progressive decrease in the number of brown trout and an increase in brook trout and rainbow trout in the canals going from the lower to the upper part of the study area (Table 6). Similar distribution was found in the 1949 and 1950 creel census of the West Gallatin River (Missouri River Basin Studies, 1951).

TABLE 6.—THE PERCENTAGES OF BROWN TROUT, BROOK TROUT, AND RAINBOW TROUT IN CANALS

Location of canals	Brown	Brook	Rainbow
Lower (3).....	82.7	5.2	12.1
Middle (6).....	27.1	55.7	17.2
Upper (4).....	0.7	70.9	28.4

The greatest concentrations of trout and whitefish fingerlings were found near the headgates of 3 canals. Fingerling trout taken downstream adjacent to the headgate of the Low Line Canal totaled 384, of which 82.5% were brown trout. The number of whitefish fingerlings found in the same area was 461. There were 287 trout and 120 whitefish fingerlings taken between the headgates of the Farmers Canal. The dominant species in this case was brook trout (83%). In 1800 feet behind the headgate of the Kleinschmidt Canal, 63 trout (79% rainbow) and 185 whitefish fingerlings were captured. A few trout and whitefish fingerlings were found far down most canals. A maximum down-canal movement observed for any fingerling was approximately 14 miles.

Non-game species were found in all of the canals studied. Small longnose suckers were numerous in all but the spring-fed Allison-Lewis Ditch and in the 3 ditches which originated nearest the mouth of Gallatin Canyon. White suckers were rare except in the Beck and Border Canal. The average length for all suckers taken was approximately 6 inches. Only 5 of those captured in 1951 were over 15 inches in total length. Thousands of sucker fry were observed in most of the canals. Adult sculpins and fry were also abundant, especially near the headgates. Dace were found in most ditches but not in large numbers.

ESTIMATED LEGAL GAME FISH LOSS

Estimates of the total numbers and pounds of legal game fish (7 inches or over in total length) were made for 11 of the 13 canals studied (Table 5). All estimates were based on the 1951 season, except for the Keughen Canal which was 1950. Each canal was divided into 3 sections for the purpose of making estimates. The first section included the

one-half mile of canal immediately behind the headgate. The second included the upper one-half of the ditch adjacent to the first section, and the third the remainder or most distal part of the canal. Reasonable effort was made to secure representative samples in each of the 3 parts. No correction was made for fish movement into or out of the canals. The sections sampled in the 11 canals ranged from 3.1% to 45.5% of their entire lengths. Because of the small samples taken in the Moreland and Heeb-Duffin Canals, these were not used in the estimates. Only Section 1 of the Clark Ditch was included because it was the only portion containing water at the time of shocking.

Fish loss showed little correlation with any of the usual physical conditions observed such as size or volume of flow. Both the High Line and Low Line Canals are large on the basis of length and volume of flow, yet the estimated 23 pounds of legal game fish in the High Line Canal and 71 pounds in the Low Line Canal are relatively small. On the other hand, the Farmers and Kleinschmidt Canals, which had the greatest volumes of flow, attracted a large number of fish (estimated over 240 pounds each). These ditches had creeks entering them, and this rather than their size may have accounted for the abundance of fish. The Beck and Border Canal, in spite of its smaller size, had an estimated poundage of fish 4 times greater than the Keughen Canal. This canal is undoubtedly influenced by Hyalite Creek which enters it. The small spring-fed Allison-Lewis Ditch had an estimated 289 pounds of legal game fish. This is the largest for any canal studied. Losses estimated for other small canals ranged from 5 to 33 pounds.

A total of 866 legal game fish weighing 352.87 pounds were taken in all samples from the 11 canals. Using this as a basis, the total estimated loss in these ditches would be 2835 legal game fish weighing 1186 pounds. If these 11 canals are representative of the 52 West Gallatin River canals in the study area, the total estimated loss would be 13,400 legal game fish weighing 5600 pounds. This area of the West Gallatin River yielded an estimated 16,100 fish weighing 10,300 pounds to the fisherman in 1949 and 16,300 fish weighing 11,300 pounds in 1950 (Missouri River Basin Studies, 1951). Suckers made up slightly more than 1% of these creel census numbers.

SUMMARY

1. Fish loss and movement was investigated during 1950 and 1951 in irrigation canals from the West Gallatin River, Montana.

2. Two-way fish weirs were employed to study fish movement in the Keughen and Low Line Canals. Debris-laden water prevented weir operation during the spring and fall segments of the irrigation seasons.

3. In the Keughen Canal there was a total of 502 initial down- and 322 initial up-canal migrants during 61 days in 1950. Trout comprised 3.5% of the total initial movement, whitefish 4.5%, and non-game species 92.0%. In 84 days of trap operation in 1951, 546 initial migrants moved down and 353 moved up the canal. Of this total movement, 6.1% were trout, 8.6% were whitefish, and 85.3% were non-game species.

4. The Low Line weir, which operated 41 days in 1951, showed an initial fish movement of 65 down- and 132 up-canal migrants. The total initial movement was 39.1% trout, 13.2% whitefish, and 47.7% non-game species.

5. All species of fish taken except cutthroat trout showed movement in both directions through either the Keughen or Low Line weirs.

6. A direct correlation existed between severe water fluctuations and trout movement upstream in the Low Line Canal. A total of 59 trout of 88% of all up-canal migrants for the entire season came out following 3 water reductions.

7. Fish loss (or gain) through the weirs while they operated was established by actual counts.

8. Thirteen canals were sampled in 1951 by shocking, poisoning or canvassing.

9. Game fish concentrations were found near headgates, near creeks where they entered a canal, and in one spring-fed ditch. Brook trout was the dominant trout species in the vicinity of creeks and springs.

10. The species composition of 1882 trout taken by sampling in 1951 was 46.1% brook trout, 37.6% brown trout, 16.2% rainbow trout, and 0.1% cutthroat trout. Fingerling trout comprised 54.7% of the total number. About 97.7% of the 894 whitefish captured were fingerlings.

11. Non-game species were numerous in most of the canals studied. Suckers predominated; their average length was approximately 6 inches.

12. Fish loss did not seem to be correlated with length or volume of flow. It was estimated that 2835 legal game fish (7 or more inches in length) weighing 1186 pounds were lost to 11 canals in the study area in 1951.

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Accepted for publication June 24, 1952.

TRAPPING VERSUS NIGHT HUNTING FOR CONTROLLING RACCOONS AND OPOSSUMS WITHIN SANCTUARIES

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The low fur prices that have prevailed for the last ten or more years have resulted in marked increases among raccoons, *Procyon lotor*, and opossums, *Didelphis virginiana*, throughout the Southeastern States. In some localities and especially on sanctuaries, where they have had an added degree of protection, over-population has become acute. Where raccoons are concerned, these heavy populations have often resulted in epidemics of gastro-enteritis or other disease that has brought about a natural reduction. Trapping has long been the accepted method of removing surplus animals from refuges, but under certain conditions night hunting with dogs may be more efficient and more desirable. Both night hunting without guns and trapping have been used experimentally for several years as control methods on the Wheeler National Wildlife Refuge. The results furnish an interesting comparison.

The Wheeler National Wildlife Refuge is located in northern Alabama, covering the middle third of Wheeler reservoir, one of the Tennessee Valley Authority's impoundments. This refuge is primarily a wintering sanctuary for waterfowl and covers a total of 41,000 acres. Of this, 22,000 are water acres at the full reservoir level and 19,000 are land acres. The land acreage includes approximately 4500 acres of mature bottom-land hardwoods, optimum raccoon habitat, and the remaining land acreage consists of agricultural fields, pine and locust plantings, marshy edges and brush.

When the refuge was first established, in 1938, opossums were common but raccoons were rare. Both species pyramided rapidly after protection began.

Although neither species can be considered highly predatory and no detailed studies were made, field observations indicated that there was considerable predation on young rabbit litters and on all ground-nesting species of birds. There was also some competition with wood ducks for tree cavities and some harassment to wintering waterfowl. Raccoon depredation in corn fields was acute in some localities. Both species impaired public relations with local farmers by raids on poultry. It was believed that the population of these mammals was far too high for available habitat and that some control was desirable. Steel-trapping was tried but failed to check the rapid increase. Alabama law provides an open season for these animals when hunted as game with dogs, beginning October 1, but barred all use of guns at night. Waterfowl do not arrive at Wheeler in numbers until November. It was felt that a night hunt could be held throughout the month of October that would aid in raccoon and opossum control with little disturbance to waterfowl. Approval was obtained from the U. S. Fish and

Wildlife Service to conduct such a hunt experimentally, although trapping was to be continued.

Under the approved plan, the refuge was divided into four hunting areas, later reduced to two, to better distribute hunting pressure. All hunting was to take place during the month of October in the hours of darkness only and dog owners were issued permits valid for the entire hunt. Report forms were attached to the permits, which were filled out and returned by the hunters at the termination of the hunt. To avoid duplication of reports, since hunting parties consisted of two to a dozen individuals, permits were issued only to dog owners.

They were allowed to bring as many guests as they desired. Guns and axes were barred from the refuge during the hunt but no limit was placed on the number of dogs used, the number of individuals making up the hunting parties, or the number of raccoons and opossums taken. Data for the hunts were obtained through the report forms and through nightly field checks with the hunters. The Alabama trapping season opens on November 20 and closes on February 20, and while both trapping and hunting were carried on during each year, the difference between the dates prevented any conflict between the two.

An average of 250 night-hunting permits was issued yearly, and including guests, it is estimated that 1,000 persons took part in these hunts each October. Fifteen trapping areas were believed to adequately cover the refuge and 15 individuals carried on the trapping during each of the three seasons concerned.

The following comparisons are based on the night hunts held in 1949, 1950, and 1951, and the trapping of the 1949-50, 1950-51, and 1951-52 seasons. The three night-hunting seasons removed a total of 1,677 raccoons and 1,479 opossums. The three trapping seasons removed a total of 359 raccoons and 763 opossums. The average annual removal through hunting was 559 raccoons and 483 opossums, while the average annual removal through trapping amounted to only 119 raccoons and 254 opossums. It should be remembered that the trapping season was much longer than that allowed for the hunts. The 1949 hunt was for the period October 1-22 while the remaining two hunts covered the entire month of October, Sundays excluded, giving a total of 72 hunting days for the three seasons.

The 1949-50 trapping season was limited to the months of December and January, while the remaining two seasons covered the full state season of November 20 to February 20, giving a three year total of 248 trapping days. Computing a daily removal by each method would show 23.3 raccoons and 20.5 opossums taken through night hunting, while trapping removed only 0.4 raccoons and 1.0 opossums per day.

These figures illustrate the superior efficiency of hunting in removing these animals, but there are still other factors that make hunting the more desirable method. With well-trained dogs there are few incidental catches of species other than those to be removed. During the three hunts a few rabbits were chased in the hollows and three skunks and one mink were killed by dogs. Although trappers were continually cautioned to make an honest effort to

avoid taking beneficial wildlife species, records show that during the three trapping seasons 87 desirable birds and 179 mammals were killed by traps, and others were caught and released, resulting in some crippling. The desirable mammals included rabbits, squirrels, and chipmunks, and the bird catch included a few ducks and coots along with shorebirds, herons, and ground-feeding small birds.

Waterfowl disturbance, an important factor on a wintering refuge of this type, must also be considered in comparing the two methods. While the night hunts involved a large number of individuals and dogs, hunting was restricted mainly to the heavily-timbered bottoms and took place entirely in October, a month when only a limited number of waterfowl are present. Trapping, on the other hand, was continued over a long period of time through the very months when southern waterfowl concentrations are at their highest peak, and resulted in considerable disturbance.

Since guns were not used, there was no crippling, as such, involved in the night hunting. However, some opossums and raccoons are caught on the ground by dogs and killed without the hunter's knowledge. Such kills, of course, are never recovered by the hunters but are believed to average less than 10 per cent of the total bag. Trapping involves much crippling to animals that pull out, wring off, gnaw off feet, or escape with traps. Data kept on this indicates that this type of crippling amounts to approximately 44 per cent for raccoons and 5 per cent for opossums.

Removal through hunting allows a considerable number of individuals to participate in a sport, whereas trapping can be regarded more as a form of work and involves a smaller number of individuals. Meat procured through hunting is better utilized than that procured by trapping, due mainly to prejudice against eating trapped mammals. These are important factors since, while the fur value of raccoons and opossums has diminished to the point where they are hardly worth skinning, their sporting and meat value remains high. Of the two methods, night hunting is the more humane. A certain amount of selectivity can be exercised that is not possible with trapping. Very young animals, when treed, are simply left unharmed by the hunters.

The above factors—more efficient removal in a short period of time, less interference with waterfowl and less damage to beneficial forms of wildlife, less crippling, better utilization of meat, and other considerations—point to night hunting as the more desirable of the two methods of removal. However, it should be remembered that the Wheeler experiment was carried on under almost ideal conditions.

No turkeys, deer, or other large game or especially rare forms of wildlife were present to complicate the hunts. Alabama law permitted hunting in October, before waterfowl concentrations occurred. Night hunting is a favorite sport in northern Alabama and good dogs were common locally. While this method is worthy of consideration wherever an over-population of these mammals occurs, there will certainly be many conditions under which night hunting cannot be used or the Wheeler

method may require modifications. Neither is night hunting a practical method of control for any other predatory mammal, with the possible exception of bobcats. Should fur prices ever again approach those of the 1920's, early fall night hunts would be impractical since they would entail too much waste of valuable fur.

Although Alabama law prohibited any use of guns at night and none were used on Wheeler hunts, the use of guns would be a great advantage in obtaining the maximum removal within the minimum amount of time. Air- or carbon-dioxide-powered rifles should be sufficient to bring down the treed animals, yet should cause little or no disturbance to other wildlife and offer little temptation to poaching.

Accepted for publication June 27, 1952.

MEASURES OF ASSOCIATION BETWEEN MOOSE AND ELK ON FEEDING GROUNDS

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INTRODUCTION

The problems incident to range utilization in Yellowstone Park by elk, moose, bison, and antelope have concerned park officials seriously for years. Preble (1911) dealt with density of elk population and the depleted range of the Jackson Hole region which adjoins Yellowstone on the south. More recently Rush (1932) and Grimm (1939) have discussed range conditions within the park with particular regard to elk. Considerable interest has been shown the moose of the region since Shiras (1913) made the initial study. Shiras, however, was not concerned with the problems of management.

This paper is a portion of a larger study of the moose of Yellowstone Park made during the summers of 1947, 1948, and 1949 which stressed food habits and the condition of the moose range. It has been evident for a number of years that the lush growth of willows, particular in the Willow Park area, Pelican Creek and Madison River valleys, as well as other areas, has been killed by over-browsing. Because of the over-crowding of the range the elk have been forced more and more into competition with the moose. Elk are primarily grazers, but when range conditions become critical they may get as much as ninety per cent of their food by browsing (Gaffney, 1941). Any study of the moose involving range utilization in Yellowstone Park would, therefore, require careful consideration of the inter-specific relationship of the moose and elk.

The total area of moose range is relatively very small as compared with that of normal elk range. The former is made up primarily of willow thickets

along streams and in marshy places, the total area of which cannot compare with the total area of grass land making up the elk range. Thus, when elk invade the moose range in large numbers it is only a short time until the willows and other edible shrubs are severely browsed or even killed completely. The solitary habit of the moose makes for an even distribution of feeding and contributes towards preservation of the food supply.

METHOD OF STUDY

Because of this competition offered the moose by the elk it was important to learn to what degree the elk did associate with the moose on the feeding grounds. The method used in this phase of the study is that described by Dice (1945). The time periods covered were from June 10 to September 10 of 1948 and 1949. The degrees of association were figured on a monthly basis to determine the variation of association throughout the summer. In this connection the term association is taken to mean mere presence together on the area and does not connote any social organization involving elk and moose.

The Willow Park section was divided roughly into six 0.8 sq. mi. areas. Natural physiographic features served as markers for the areas. Each sample was given two dimensions, area and time. The sampling was done during the time of day when both species concerned were feeding in greatest numbers and in closest proximity. This controlled sampling gives the highest degree of association rather than an average degree. The terrain is such that the entire area of the marked sections can be observed by driving along the highway and counting the number of 0.8 sq. mile areas that had moose by themselves, elk by themselves, and the two together. Area 1, from 7 P.M. to 8 P.M. constituted one sample; from 8 P.M. to 9 P.M. another sample, etc.

MEASURES OF ASSOCIATION

In this discussion moose are designated as species "*A*" and elk as species "*B*". The number of samples in which moose occur alone or with elk is "*a*" and the number of samples in which elk occur alone or with moose is "*b*". The number of samples in which both species occur together is "*h*", while "*n*" is the total number of samples. The derivation of the formulas used is clearly discussed by Dice (*ibid*).

The coefficient of association is a measure of the number of samples in which both moose and elk occur as compared to the number of samples in which they could be expected to occur together by chance. The formula for this expression of association is hn/ab. A coefficient of association of 1.0 would show that both moose and elk occurred together in exactly the same number of samples as expected by chance. A coefficient of more than 1.0 would show that they occur together more frequently than expected by chance. For example, a coefficient of 1.5 would mean that they occurred together 50 per cent more frequently than could be expected by chance. As Dice (*ibid*) points out, the coefficient of association is not a direct measure of association between the species, but a measure of the deviation of the number of their occurrences together from the number expected by chance.

Two direct measures of association are

provided by the association index and coincidence index. The association index compares the association of one species with another. One species is used as the basis and the other compared with it. The arithmetical value of the measure will, therefore, vary depending on the basis used. The formula used for this measure is h/a or h/b, depending on which species, moose or elk, is used as the basis for comparison.

The coincidence index is an expression of the association between both species compared and is intermediate in value to the association indices of moose/elk and elk/moose. The formula used here is $2h/a+b$.

VALUES OBTAINED

Table 1 gives the values of the various measures discussed for the three summer months of two years during which this aspect of the problem was carried on. For June 10 to July 10, 1948 moose and elk occurred together in the samples 65 per cent more frequently than would be expected by chance alone; for the two remaining periods they were found 120 and 14 per cent more frequently than would be expected. It was surprising to see that during August 11 to September 10 of each year the variation from the number of chance associations decreased from the previous periods. It was previously thought that as fall approached and the elk bunched together and came down from the higher elevations that both species would be found feeding together more frequently. Perhaps it was just this banding together of the small groups and solitary individuals that reduced the number of associations between elk and moose. It must be pointed out here that

TABLE 1.—MEASURES OF INTER-SPECIFIC ASSOCIATION BETWEEN MOOSE AND ELK

Measure of Association		June 10 to July 10		July 11 to Aug 10		Aug. 11 to Sept. 10	
		1948	1949	1948	1949	1948	1949
Coefficient of Association		1.65	1.51	2.20	1.63	1.14	1.48
Coincidence Index		0.40	0.38	0.47	0.39	0.38	0.41
Association	Elk / Moose	0.30	0.28	0.38	0.29	0.28	0.31
Index	Moose / Elk	0.58	0.55	0.62	0.57	0.59	0.61

in all of these measures of association no account of numbers of individuals is considered. To my knowledge no method has yet been worked out for measuring inter-specific association which at the same time considers the very important factor of density of population.

The association indices show that for June 10 to July 10, 1948 in 30 per cent of the samples in which moose occurred, they were associated with elk; and elk were associated with moose in 58 per cent of the samples. For the two remaining months moose were associated with elk in 38 and in 28 per cent of the samples, respectively, and elk were associated with moose in 62 and 59 per cent of the samples. The figures for 1949 closely parallel those of 1948, except for the coefficient of association for July 11 to August 10, 1948. I cannot account for the difference being so much greater in this instance. The values obtained for the association indices indicate that moose are less strongly associated with the elk than elk are with moose. This indicates a one-sided relation that is due largely, I believe, to the unnaturally high concentration of elk which has been brought about by more or less artificial effects of sanctuary in the park. If there were adequate grazing land available to the elk and they were free to feed on such land, I think this unilateral tendency of association on the moose feeding grounds would tend to disappear. The tendency of elk to feed in bands rather than as isolated individuals like moose may be a contributing factor to the unilateral association. The coincidence indices show to what extent the two species were associated when both are compared together. This measure might be said to indicate the average degree of association between the two. The average for the six time periods is 40 per cent. No antagonism between moose and elk or avoidance of each other were observed at any time. The only apparent factor which brought them in contact with each other was the presence of food.

The data were subjected to the chi-square test, resulting in values of X^2 of 25.442 for the period of July 11 to August 10, 1949 and of 21.466 for June 10 to July 10, 1948. These tests indicate that the sampling method gives a true picture of the association of moose and elk.

SUMMARY

A study was made to determine the amount of association between moose and elk on parts of the normal moose range in Yellowstone Park.

Three measures of association were used. The derivation and theoretical bases for these measures are clearly set forth by Dice (1945).

The data show that there is a unilateral tendency of association on the feeding grounds. The elk are associated with moose as much as 62 per cent more frequently than could be expected by chance alone, whereas moose are associated with elk as little as 28 per cent as frequently as could be expected by chance. It appears to be evident that elk are using the moose range more heavily, resulting in damage which may seriously affect the Yellowstone moose population.

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Accepted for publication July 10, 1952.

THE NECEDAH REFUGE DEER IRRUPTION [1]

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On the Necedah National Wildlife Refuge in central Wisconsin the deer population built up from a subnormal to a critically high level in six years. An understanding of this development may help wildlife managers to prevent similar irruptions and may hasten public acceptance of proper deer-management measures. For this reason the sequence of events leading to the irruption have been studied and recorded. The four objectives of the study are: first, to report on the behavior of the deer population during the irruption; second, to point out the effect of the deer population on the range vegetation; third, to evaluate the results of archery and gun hunting; and fourth, to show that herd reduction is one of the most satisfactory remedies for an over-populated range.

In their survey of over-populated deer ranges in the United States, Leopold, Sowls, and Spencer (1947) made reference to the Necedah Refuge as one of three irruptive areas in Wisconsin where the deer population was still increasing in 1946. These writers have also described approximately 100 deer problem areas in 30 states. They found it necessary to classify the areas into three types: irruptive, trouble, and chronic. According to their classification the Necedah Refuge was an irruptive area which they have defined as, "An area in which the deer population has

[1] The authors are indebted to Otis S. Bersing of the Wisconsin Conservation Department for his keen interest and tabulation of much of the kill data and to other members of the Department who cooperated with the Fish and Wildlife Service in the management of the herd. The browse survey assistance given by Vern E. Rudolph of the Necedah Refuge is also appreciated.

hurt the range by overbrowsing, or itself by malnutrition, or both. Any herd which must be fed to avoid starvation is in the irruptive stage."

DESCRIPTION OF THE REFUGE

The Necedah National Wildlife Refuge is located in the central portion of Wisconsin in Juneau County. The 40,000 acres in the refuge is a part of the 100,000-acre Federal wildlife area formerly known as the Central Wisconsin Game Project, Necedah. The balance of Federal lands (60,000 acres) adjoining the refuge, mostly to the west, are now called the Meadow Valley Unit of the Central Wisconsin Conservation Area and are managed by the Wisconsin Conservation Department under lease.

The topography is that of the gently undulating bed of Glacial Lake Wisconsin. It is characterized by numerous ponds and marshy areas separated and broken up by sandy ridges and islands. The refuge was established for waterfowl and a network of old drainage ditches maintains the water levels in the numerous pools.

The original vegetation on the area was altered greatly prior to the establishment of the refuge in February, 1939 by destructive logging practices, numerous fires, and unwise drainage projects. Many abandoned farms which were purchased by the Federal Government to establish the refuge attest to the submarginal nature of the area for agriculture. As part of the refuge development, coniferous tree plantations, 5 to 20 acres in size, containing mixtures of jack and red pine, and white and Scotch pine, have been established and are now (1950) 10 to 15 years old.

The natural vegetation is largely a jack pine-scrub oak mixture on the uplands and aspen, birch, and several species of shrub willows in the lowlands. Although the tree cover is related climatically to the oak-hickory forest, the sandy nature of the soil has permitted a southward extension of the northern pines, especially jack pine. The present conifer hardwood type is composed mostly of jack pine and scrub oaks, the latter principally jack oak (*Quercus ellipsoidalis*). Large white and red pines were once abundant but are now present only in limited numbers.

BEHAVIOR OF THE IRRUPTION

The sequence of events in the early stages of the Necedah irruption is similar to those of other much publicized irruptions. Leopold, Sowls, and Spencer (*op. cit.*) report, "Buck laws, predator control, and over-large refuges, working in combination to allow undue multiplication of breeding females, seem to be the pre-disposing causes of irruptive behavior." The causes of the Necedah irruption may be attributed to the protection given the deer by the refuge; the legal restrictions against killing does under the Wisconsin laws; the movement of deer onto the refuge in the winter time; and the absence of effective deer predators. The Necedah Refuge deer must be regarded as part of the Wisconsin deer population for they move freely back and forth between the refuge and adjacent deer territory. Except as prevailing conditions for deer may be altered by practices peculiar to the refuge operation, deer frequenting the area are subject to influences and trends similar to those affecting deer not on refuges. For this reason it seems important to explain occurrences on the

refuge against a background of what was happening to Wisconsin deer in general during the period under discussion.

Historically, Wisconsin had gone through the same years of low deer population as other states in the region. About 1920, deer commenced to increase as a result of many circumstances favorable to them such as better law enforcement, the establishment of the one-buck law in 1915, past logging operations which furnished ample winter browse, and similar influences. Deer drives were made annually between 1935 and 1941 and a total of 617 drives indicated a statewide average of 45 deer per section (Swift, 1946). By 1943 a "peak" population had been recognized in many localities and the buck law period (1920-1942) ended in favor of a split season—a four-day season on forked-horn bucks, then a three-day rest period followed by a four-day antlerless season. For the first time in twenty-five years antlerless deer were killed and 158,000 hunters bagged 105,000 deer. Public reaction was great following the 1943 split season and only forked-horn bucks were killed for the next five years. Nineteen forty-nine marked a turning point in the state's deer harvesting program and in a five-day antlerless season nearly 160,000 deer were killed. A total of 327,000 deer were harvested in the two-year period. The harvest represented more deer than had been killed in Wisconsin in six previous seasons (1943-1948).

In central Wisconsin the kill increased from 4,575 in 1944 to 8,828 in 1945 (93 per cent). In 1946 more than 14,000 deer were bagged and the kill increased 61 per cent compared to 1945. The central area kill remained about the same in 1947 (13,596) although the Juneau County harvest was 3,678, the highest in the state. This high kill was due in part to the Necedah Refuge which formed one-third of the county total. A forked-horn buck season followed in 1948 and the kill was much lower on the refuge (100 bucks), in Juneau County (1,193), and in central Wisconsin (9,152). More liberal hunts were held in 1949 (antlerless) and 1950 (any-deer) and increased kills resulted on the refuge (580 plus 18 taken by archers in 1949; 248 plus 19 taken by archers in 1950), in the county (7,086 in 1949, 3,621 in 1950), and in the central area (40,141 in 1949; 31,760 in 1950). Although the more liberal seasons outside the refuge resulted in much heavier kills (1949 and 1950) the refuge deer population had been reduced by 1948 and it did not respond in a like manner.

The progressive steps in the deer irruption may be reconstructed in a general way as follows:

1. When the refuge was established, and for several years thereafter, deer were less abundant on the refuge than on average Wisconsin deer range.
2. Under favorable refuge conditions, including nearly complete protection from 1936 to 1946, deer increased from an estimated 6 per square mile to 80 per square mile.
3. Removal of adequate numbers of deer by archers and gun hunters from 1945 through 1950 apparently reduced the deer population to a level which the range could support.

Fig. 1 shows graphically the rise and fall of the populations over the years from 1939 through 1950, including the

hunting removals during the latter half of the period. The population estimates presented have been derived from roadside track counts, deer drives on sample areas, airplane counts, and probably in some instances from guesses by those familiar with the area, particularly the refuge managers.

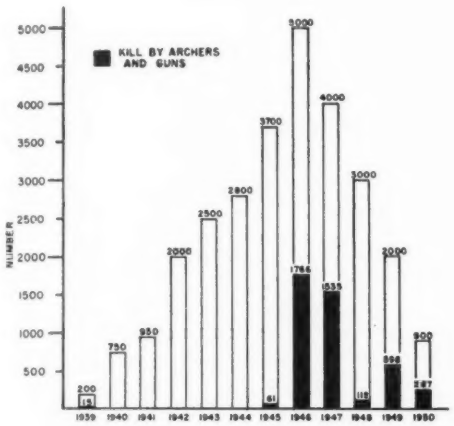

FIG 1 POPULATION AND KILL, 1939–1950.

In retrospect, danger signals of a too rapid increase of deer on the refuge are apparent. The population was low in the winter of 1936-37—approximately 6 deer per square mile (375 on the refuge) according to Hamerstrom and Blake (1939)—and lower still in 1939 when 3.2 deer per square mile (200 on the refuge) was the estimate. From this low point the increase was rapid. A jump from 200 in 1939 to 750 in 1940 is credited to a good fawn crop plus movement of deer into the refuge; and similar factors may account for the 1942 jump to 2,000. At any rate, by August 1942 the refuge manager had become alarmed about the size of the deer herd and wrote in his report, "The refuge is really becoming a deer haven, and . . . . . within the next three or four years it might be desirable to remove some of the herd." About three years later a second alarm was sounded when the manager's report for April 1945 states, "Three deer yards visited during the winter showed extensive browsing. This is the first time in this refuge that a definite (browse) line could be noticed." And as final confirmation of previous warnings, in April 1946 the refuge manager's report states, "The white-tailed deer herd has reached the problem stage. . . . . Actual starvation occurred, 12 dead deer were found after the snow left. Unless large numbers are removed, wholesale starvation next winter is possible if there is much snow." It is significant to note that 10 of the 12 dead deer were fawns.

It should be noted that the danger signal on which action should have been taken to reduce the population was contained in the refuge manager's report in August 1942, "The refuge is really becoming a deer haven. . . . .". Had reduction taken place at this time there is good reason to believe that the productivity of the area could have been maintained at a much higher level than is now the case with a much greater return to hunters during the intervening period.

However, because of legislative restrictions, failure to recognize the need for immediate action, lack of public support, and other hindrances common to such situations, no action could be taken until the peak of the irruption was reached in the fall of 1946 when the population was estimated at 5,000 deer. At this time the deer population was in the third or starvation stage of the irruptive sequence as described by Leopold (1943). To reduce the popula-

tion and thus relieve the critical pressure on the browse, plans for the first gun season and the second consecutive archery season were drawn up with the Wisconsin Conservation Department in 1946. Hunting in 1945 and 1946 and in four subsequent seasons resulted in a harvest of 4,345 deer; (Fig. 1 and Tables 1 and 2) and the estimated population was 18,600. Had the population and kill been evenly spread over the 6-year period (1945-1950) the removal would have amounted to 23 per cent of the population. Drawing on the records of deer hunting in other areas where deer herds have withstood an annual hunting reduction of about 35 per cent, plus the fact that the deer in the Necedah area had been increasing rapidly for several years, we feel justified in making this assumption: had approximately 35 per cent of the deer population been removed each year beginning in 1942, it seems probable that about 9,000 deer could have been harvested over the 9-year period involved. This would have meant orderly hunting seasons, more than twice as many deer for the hunters, but of more importance than these, the protection of the deer range from severe overbrowsing and lowered carrying capacity resulting from such over-utilization.

EFFECT ON THE RANGE

In their discussion pertaining to the appraisal of deer irruption areas, Leopold, Sowls, and Spencer (*op. cit.*) state, "A common error is to try to appraise by census rather than by browse conditions. The public can dispute endlessly about censuses, but cannot dispute dead browse plants." An evaluation of the degree of utilization of browse of varying degrees of palatability was made on the refuge on February 18, 1946, by the Wisconsin Conservation Department. Seventeen men, divided into eight crews, surveyed 14,100 acres (35 per cent) of the refuge, and made statements based on visual impressions of the deer range. They reported 11,640 acres (83 per cent) were heavily browsed while utilization was moderate on 2,460 (17 per cent). For the refuge as a whole, the browse supply

TABLE 1.—SUMMARY OF BOW AND ARROW HUNTING—1945 TO 1950

Year	Season	Days	Bag Limit	Bucks	Does	Total	Resident kill	Non Resident kill	Open Area Sq.Mi.	No. Hunters	% Successful
1945.....	Sept. 29–Nov. 12	45	Any Deer	28	33	61	41	20	50	2,000	3.0
1946.....	Sept. 28–Nov. 11	45	Any Deer [1]	69	60	129	108	21	50	3,000	4.3
1947.....	Sept. 27–Nov. 11	46	Any Deer	69	42	111	84	27	54	4,000	2.7
1948.....	Sept. 25–Nov. 7	43	Any Deer	12	6	18	12	6	54	3,000	.6
1949.....	Sept. 24–Nov. 7	43	Any Deer	9	9	18	13	5	53	2,000	.9
1950.....	Sept. 23–Nov. 6	45	Any Deer	9	10	19	6	13	53	2,000	.9
	Total.....			196	160	356	264	92		16,000	2.2 Average

[1] The law specified the deer must be one year of age or older.

TABLE 2.—SUMMARY OF GUN HUNTING—1946 TO 1950

Year	Season	No. Days	Bag Limit	Bucks			Does			Total kill	Open Area Sq.Mi.	Kill Sq.Mi.	No. Hunters	% Successful
				Adults	Fawns	Total	Adults	Fawns	Total					
1946	Nov. 23–Dec. 1	9	1 Antlerless	2	277	279	1,113	239	1,352	1,631 6* 1,637	50	53	2,226	74
1947	Nov. 22–30	9	1 Forked-horn Buck	..	...	500	.....	...	.....	500	50	10	1,500**	33
1947	Dec. 6–14	9	1 Antlerless	60***	183	243	473	208	681	924****	54	26	2,500*****	36
1948	Nov. 20–28	9	1 Forked-horn Buck	..	...	100	.....	...	.....	100	54	2	3,340	3
1949	Nov. 19–23	5	1 Any Deer (except bucks with antlers exceeding a two-inch fork)	..	...	183	.....	...	397	580	36	16	2,837	20
1950	Nov. 18–24	7	1 Any Deer	..	...	128	.....	...	120	248	36	7	3,068	8
	Total.....			62	460	1,433	1,586	447	2,550	3,989			15,471	21 Average

* Reports are incomplete on 6 deer making the total 1,637.

** Estimate by refuge manager.

*** The adult bucks were legal because they had shed their antlers.

**** Kill data for Necedah Refuge—924; and Meadow Valley Unit—594 were not recorded separately as to sex and age class. This information was obtained by applying the per cent of total kill figures contained in the article by Bersing (1948).

***** Number of hunters was calculated from the total of 4,116 reported by Bersing (1948) for both the Necedah Refuge and Meadow Valley Unit. 60.8 per cent of the kill was from the Necedah area and 60.8 per cent of 4,116 equals 2,500 hunters.

was critical on as much as half of the area and the rest was rapidly approaching this stage.

In March 1950, in order to determine the condition of the range more accurately, the authors conducted a detailed range survey. The deer browse survey method described by Aldous (1944) was used since the reliability of the results can be subjected to a statistical analysis. It consists of selecting an adequate series of 1/100-acre plots on which the density (each plot represents 100 per cent and density is that percentage of the plot area covered by vegetation) and the degree of browsing (the percentage of the annual growth within reach of the deer, i.e., 7 feet). In addition, a new index of browsing [4] was devised. The basis for the index is the assumption that when 40 per cent or more of the annual growth is eaten, browsing is considered heavy. It is believed this index furnishes a more useful indication of browsing intensity than methods previously used.

The field data on browse utilization were obtained by studying 667 plots of 1/100 acre each. A restricted random sampling was used and the refuge was subdivided into 12 units, 4 to 6 square miles in size.

[4] For convenience, the index of browsing is expressed in per cent. When 40 per cent or more of the annual growth is eaten the browsing is considered heavy. The index is determined by multiplying the total of all browsing from the field tally sheets by 2½ and dividing this amount by the number of plots in which the species was present. For easy comparison, 100 per cent is considered the point where heavy browsing begins and the index is related to that point. Differences in the ability of species to withstand browsing are recognized, although the 40 per cent point is applied to all species for comparative purposes.

Analysis of the 1950 browse survey (Table 3) shows that the five most important winter foods are willow, aspen, jack pine, oak, and juneberry. Together they formed 93 per cent of the winter diet. Willows, in addition to their importance as winter food, also furnished both spring and summer browse. Deer showed preferences for certain species of willow, such as dwarf willow (*Salix tristis*), although separating "food willows" from other willows is difficult. The scrub oaks were important not only for the browse produced but equally important for the mast in years when acorns were plentiful. Deer consume the acorns in the fall and continue to feed on them into the winter until the snow reaches a depth of about 15 inches. Sixteen other browse species (Table 1) made up the remaining 7 per cent of the diet but poor distribution and low palatability in some instances accounted for low usage of these species.

Palatable browse species such as sumac, wintergreen, red osier dogwood, and holly were listed as severely browsed in 1946 but they did not appear in the 1950 survey. Low growing plants such as wintergreen may have been covered by patches of snow to some extent but it is more likely that past heavy browsing either eliminated the highly preferred foods or greatly reduced their abundance. Although no recovery in the above palatable species was noted in 1950, some range improvement was evident as the browsing pressure on other important winter foods was greatly reduced following herd reduction. The low indexes of browsing for these species attest to their usage as follows: oak 5.5 per cent; jack pine 8.1 per cent; aspen

TABLE 3.—PER CENT OF WINTER DEER BROWSE EATEN AND AVAILABLE AND INDEX OF BROWSING

No. of Plots: 667

Browse Species	Per cent of Plots Present	Average Density	Average Degree of Browsing	Utilization Factor	Per cent of Food Eaten	Per cent of Browse Available	Index of Browsing (Per cent)
Jack pine (*Pinus banksiana*)	32	3.3	3.2***	10.56	22.4	18.1	8.1
Willow (*Salix* spp.)	25	3.0	4.5***	13.50	28.6	16.4	11.3
Aspen (*Populus tremuloides*)	31	2.8	4.2***	11.76	24.9	15.3	10.6
Juneberry (*Amelanchier* spp.)	8	0.8	4.4	3.52	7.5	4.4	11.1
Red pine (*Pinus resinosa*)	3	0.1	0.5	.05	0.1	0.5	1.3
Sweet fern (*Myrica asplenifolia*)	22	2.8	0.5	1.40	2.9	15.3	1.2
Oak (*Quercus* spp.)	28	2.0	2.2***	4.40	9.7	10.9	5.5
Hardhack (*Spiraea tomentosa*)	12	1.0	0.4	.40	0.8	5.5	0.9
Bog birch (*Betula pumila*)	5	0.2	1.8	.36	0.7	1.1	4.5
Dewberry (*Rubus* spp.)	6	1.2	0.1	.12	0.2	6.2	0.3
Rose (*Rosa* spp.)	*	0.1	1.6	.16	0.3	0.6	4.1
Paper birch (*Betula papyrifera*)	3	0.2	0.5	.10	0.2	1.1	1.2
Raspberry (*Rubus* spp.)	*	0.1	1.2	.12	0.2	0.6	3.1
Tag alder (*Alnus incana*)	*	0.2	0.8	.16	0.3	1.1	2.1
White pine (*Pinus strobus*)	*	**	1.6	....	....	....	....
Cherry (*Prunus* spp.)	3	0.2	1.2	.26	0.5	1.1	7.0
Blackberry (*Rubus* spp.)	*	0.2	0.0	....	....	....	....
Hazel (*Corylus* spp.)	*	0.1	3.7	.37	0.7	0.6	9.2
Leatherleaf (*Chamaedaphne calyculata*)	*	**	15.0	....	....	....	....
Honeysuckle (*Lonicera* spp.)	*	**	0.0	....	....	....	....
Maple (*Acer* spp.)	*	**	0.0	....	....	....	....
Unidentified	*	**	0.0	....	....	....	....

* Present in less than 1 per cent of the plots.
** Average density is less than .05 per cent.
*** Standard error of sampling approximately plus or minus .3 per cent.

10.6 per cent; juneberry 11.1 per cent; and willow 11.3 per cent.

The effect of the deer on the browse plants during an irruption clearly demonstrates the rapidity with which deer in excessive numbers can severely damage or destroy the carrying capacity of their range. The only apparently feasible remedy is herd reduction.

ARCHERY HUNTING

The central location of the Necedah Refuge, with its large deer population and liberal hunting regulations, attracted archers from all parts of Wisconsin and from eleven states including such distant points as Texas and California. The refuge also served as host to the Wisconsin Bow Hunters Association which held its first and second annual fields days on the area in mid-September of 1945 and 1946. One hundred-fifty archers and 200 spectators came the first year while the second year attracted 450 competing bowmen and 1,000 visitors.

The refuge was open to bow hunting after six years of complete protection and annual seasons have been held each fall (1945-1950) beginning in late September and ending by mid-November. One deer (any age) has been the bag limit for all seasons with the exception of 1946 when the deer had to be at least one year of age. Hunting was done only on a permit basis in 1945 (limited to 2,000) and in 1946 (limited to 3,000). In six open seasons 16,000 archers bagged 356 deer (Table 2) and the refuge alone accounted for 38 per cent of the state's archery kill during the first three years (1945-1947). However, after gun hunting removed approximately 3,000 deer, less than one per cent of the Necedah bow hunters were successful. Knowledge gained from bow hunting indicates the bowmen did little to relieve the overabundance of deer (8 per

cent of the total) and that archery hunting cannot be used effectively as a method to crop deer, especially on problem areas.

GUN HUNTING

Two special gun seasons (1946 and 1947), which permitted shooting antlerless deer, made it possible to rapidly reduce the deer population at its peak and prevented additional winter losses. Of more importance, the reduced population relieved the critical pressure on the browse plants. The special hunts also provided a testing ground for Wisconsin's first experiment in controlled deer hunting.

Three out of four hunters got their deer the first antlerless season while only two out of three were successful the second season. During the five years of hunting (1945-1950) more than 15,000 hunters bagged nearly 4,000 deer and approximately three-fourths of them were taken the first two years (Table 3).

The first antlerless season ran concurrently with the forked-horn buck season outside the refuge. The second antlerless hunt was held in December (Dec. 6-14) following a nine day open season on refuge forked-horn bucks in November (Nov. 22-30).

Fear of hunting accidents and casualties if too many hunters were attracted to the extremely accessible and easy-to-hunt refuge made it necessary to exercise control under a permit system. More than 5,000 applications were received the first year (1946) and 3,000 permits were issued but only 74 per cent of the hunters (2,226) used their permits. The nine-day season was divided into three 3-day hunting periods and 800 hunters were allowed to hunt the first period and 1,100 were permitted on the area the second and third periods. It was a very orderly hunt and apparently the hunters were concerned over their personal welfare since there were no hunting accidents. Twenty thousand applications were received for the second special hunt (1947) and this included the adjoining Meadow Valley Unit (under state management) as well as the Necedah Refuge. Only 6,000 permits were issued for both areas and of the 4,000 that were used, approximately 2,500 hunted on the refuge. The nine-day season was divided into seven 3-day periods with periods overlapping.

Thirty-one per cent of the antlerless kill (1946) consisted of fawn deer and the ratio of fawns to adult does was .4 of a fawn per doe. The percentage of fawns (31 per cent) appears to be satisfactory but it must be remembered that a large number of adult does (1,113) were needed to produce them. Apparently the low productivity (.4 of a fawn per doe) was due to the poor winter range which did not provide enough palatable browse to permit the does to produce as many fawns as they normally do in good areas. The following year the kill consisted of 42 per cent fawns and the fawn-doe ratio increased to .8 of a fawn per adult doe. Evidently the removal of about 1,600 deer by hunting was responsible for increasing the productivity of the deer population.

DRESSED WEIGHTS [5]

The weights of deer usually reflect the quality and quantity of the browse

[5] Viscera removed but often the liver and heart remained in the carcass.

plants on the winter range. For that reason weight information was obtained from the over-populated refuge (and nearby areas) and from good range elsewhere in central Wisconsin. A comparison of the weight data shows the majority of the deer killed on good range weighed more although the differences are not great. The average weight differences between poor and good range were: 7 pounds for adult bucks; 2 pounds for adult does; and 2 pounds for female fawns (Table 4). Male fawns weighed 4 pounds less and the difference may be due in part to a high percentage of 5-months-old fawns in the good range sample. However, the weight differences for the adult deer are significant and the lower weights reflect the poor range found on the refuge and adjacent areas.

SUMMARY

1. The deer population on the 40,000-acre Necedah National Wildlife Refuge in central Wisconsin increased in typical irruptive form from an estimated 6 deer per square mile in 1936 to a peak of 80 deer per square mile in 1946.

2. The causes of the irruption may be attributed to the complete protection afforded the refuge deer, the operation of the Wisconsin Buck Law outside the refuge which prohibited the killing of does, the movement of deer onto the refuge in winter, and to the lack of effective predators.

3. The danger signal on which action should have been taken to reduce the population was given in the fall of 1942. However, because of legislative restrictions, failure to recognize the need for immediate action, lack of public support, and other hindrances common to such situations, no action could be taken until 1946 when the population reached a peak of 5,000 deer.

4. The deer population had reached the third or starvation stage of the irruptive sequence before gun hunting was permitted. Twelve deer were known to have died of starvation and the majority of them were fawns.

5. The detailed deer browse survey made in 1950 showed that the five most important winter foods were: willow, aspen, jack pine, oak, and juneberry. Together they made up 93 per cent of the winter diet. Palatable browse species such as sumac, wintergreen, red osier dogwood, and holly were listed as severely browsed in 1946 but they did not appear in the 1950 survey. However, some range improvement was evident by 1950 as the browsing pressure on

TABLE 4.—DRESSED WEIGHT OF DEER *

Area	Bucks				Does			
	Adults		Fawns		Adults		Fawns	
	No.	Ave. Wt.	No.	Ave. Wt.	No.	Ave. Wt.	No.	Ave. Wt.
Necedah Refuge and Adjacent areas.[1]	337	92	108	56	386	95	103	52
Good Range Outside Refuge [2] (Central Wisconsin)	129	99	41	52	169	97	38	54

* Viscera removed but often the liver and heart remained in the carcass.
[1] Represents 247 deer weighed in November and December 1947 during the forked-horn buck and antlerless deer season on the Necedah Refuge and adjacent areas. Also includes 687 warden-seizure deer weighed at the nearby Meadow Valley and Babcock Stations (1945–1947).
[2] Represents 377 deer taken on good range in central Wisconsin for the years 1945 to 1947 (3 year average).

other winter foods was greatly reduced.

6. The irruption was stopped by the harvest of 1,766 deer in the fall of 1946 and brought under control by annual hunting seasons. Since 1945 the bowmen bagged 356 deer and the gun hunters removed 3,989. Archery and gun hunters together bagged 4,345 deer in six open seasons (1945-1950).

7. Fawn productivity was only .4 of a fawn per adult doe in 1946 and it was increased to .8 of a fawn per adult doe in 1947 as a result of harvesting 1,600 deer. The range was in poor condition when the herd was at its peak and the does were unable to produce as many fawns as they normally do on better range.

8. A comparison of deer weights on the over-populated refuge (and nearby areas) with those from good range in central Wisconsin showed the majority of the poor range deer weighed less. The weight differences for the adult deer are significant and the lower weights reflect the poor range found on the refuge in 1946 and 1947.

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Accepted for publication July 28, 1952.

REPRODUCTION OF YELLOWSTONE ELK

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Overpopulation of elk (*Cervus canadensis nelsoni*) has resulted in widespread deterioration of winter range in the Yellowstone River drainage of Yellowstone National Park and has made control of elk numbers an important problem. Statistical information on the size of the herd, population trend and expected increase has often been inadequate for the planning of a satisfactory control program. Consequently, the National Park Service made a comprehensive quantitative study of reproduction and survival of elk in this herd. Data pertaining to prenatal phases of reproduction are covered in this paper.

Killing programs in Yellowstone Park have provided excellent opportunities for the collection of quantitative data. Mills (1935, 1936) and West (1937, 1941) published part of their data from the first two slaughters, and Murie (1951a) published his material from 1943. Relatively large samples taken between 1949 and 1951 in cooperation with the Montana Fish and Game Department added sufficient data to warrant this quantitative treatment. These recent records are first published in this report.

Biologist Joe E. Gaab and Junior Biologist Bert Angstman, Montana Fish and Game Department, collected almost half of the field data in 1950-1951 and assisted in compiling data for that season. Special thanks are due the many people who assisted in the field between 1949 and 1951, especially District Park Ranger Rudolf L. Grimm of Yellowstone National Park and Ezra B. Richan, employee of the Montana department. Olaus J. Murie, Moose, Wyoming, and Philip L. Wright, Montana State University, helped determine the ages of several elk. For statistical analysis of data I am endebted to Robert L. Shotwell, U. S. Bureau of Entomology and Plant Quarantine, and Joe J. Livers, Montana State College. I also wish to thank Don C. Quimby, Montana State College, and the many others who helped in preparation of the manuscript.

Elk Herd and Range

For at least half a century the so-called "northern Yellowstone elk herd" has been so large that winter range for the elk and associated ungulates has been inadequate. Early census figures are questionable; those since 1934 indicate that from 8,000 to 12,000 elk have been in the herd in late winter after hunting (outside the park), slaughter and trapping. No definite trend of increase or decrease during that period is indicated. Greatest known cause of fluctuation has been erratic hunting success.

Elk removed from the herd between 1934 and 1951 number about 40,550 (an average of 2,385 per year) with 77 per cent by hunting, 6 by slaughter in the park, 7 by trapping, and 10 by winter-kill. Operational reductions were generally non-selective. All natural

losses are considered winter-kills. No attempt is made to appraise losses of elk between late spring and fall. The simple method of computing the size of the herd is to deduct winter losses from the number counted in or computed for late winter, allow for increase up to the next fall, and deduct animals taken in ensuing operations. Censuses are needed rather frequently to provide new starting points for this system.

Summer range of this elk herd includes all of the park except the extreme southern part and the northwest corner. In addition, adjacent National Forest land is used by a few elk. Generally, forage is abundant on summer range and range condition is considered satisfactory by the National Park Service.

Winter range is only a small part of Yellowstone Park. It includes most of the Yellowstone and Lamar River drainages which lie below the general plateau level. To the north, considerable National Forest land is reserved for wildlife range, but in recent years it has been used by only a small fraction of the Yellowstone herd.

Early-winter range is in rather good condition in regard to sagebrush-grassland; deciduous browse types are becoming less productive and smaller. This range provides considerable herbaceous forage but becomes unavailable to grazing animals in late winter—usually February to early April. Late-winter range is predominantly of the sagebrush-grassland type (in many places reduced to grassland), much of which is in poor condition due to overuse for several decades. Forage utilization here is usually heavy, and nutritional deficiency becomes apparent in elk losses in occasional winters.

The general shortage of browse and of all forage in late winter may have a significant effect on reproduction of the herd. No information is available on this and no allowance has been made for it in computing herd increase over the years.

TERMINOLOGY

Ages of elk are designated as: I—calf (about 7 months), II—yearling (about 19 months), III—two-years-old (about 31 months), and IV+three years plus (about 43 months and older). Similar age designations are used for elk during the rut in September and October, even though animals are approximately three months younger. All females which have passed their first birthday are called "cows" and the males "bulls." Males during their second year are "spikes."

Percentages are rounded to the nearest whole number. "Significant" is used to denote a difference at the 95 per cent level of probability; "highly significant", a difference at the 99 per cent level.

SOURCES OF DATA

1935 Slaughter

All (242) of the elk studied in January and February by Mills (1935) were at trapping sites at the upper and lower limits of winter range. Ninety-seven per cent were killed at the traps, the remainder died from natural causes or wounds inflicted by hunters. Inclusion of animals which died from natural causes could have biased incidence of pregnancy but very slightly. About 13 per cent of his specimens were selected for slaughter; ". . . the rest were taken regardless of sex, age, or condition."

No information is available as to age of animals selected. For this study, his statement, ". . . the data taken should represent an average cut of the herd," is considered sufficient.

Statements by Mills (1935, 1936) concerning ages of females examined for pregnancy are confusing. It appears (Mills, 1951) that there was a slight chance that a very few yearlings were included with females of older age. Since the likely error would be very small, females used for pregnancy data are considered to be older than yearlings. Mills (1936) identified yearlings by tooth succession, hence separation of them from older animals is acceptable by present standards.

1937 Slaughter

West (1937) apparently confined his examinations to animals handled at traps during the slaughter operation. During January and February 1937 he examined 220 elk, mostly on the upper winter range. Animals caught in the traps were slaughtered and examined without selection.

The ages of females examined for pregnancy are difficult to understand. West (1951) believes that the 134 cows examined for pregnancy were of age groups III and IV+. Criteria used for aging in 1937 are not available; however, West's later work (1941) indicates that he was familiar with at least some phases of tooth succession among young elk.

1943 Slaughter

During this reduction, elk were shot without selection on most of the range near the highway. Some were killed in late 1942; however, Murie's (1943) examinations were all made in January 1943, probably mostly on the intermediate and upper range.

Murie apparently examined 98 of the female elk and Ranger Grimm, 58. Murie (1951b) selected animals of age III and IV+. Grimm believes that his may have included some females of age II, but the entire group is here considered to be age III and IV+.

1949-50 Slaughter

Again, all elk were killed without selection on most of the open range near the highway. Total animals killed between December 19 and January 18 was 513. Some rather long-range shooting was encountered and the larger targets probably were selected to a minor degree. This, of course, would tend to reduce the proportion of calves killed.

Data were obtained on 507 elk. The other 6 animals became unavailable for reasons beyond our control. Usually records were made while the animals were being hog-dressed at the site of killing. In cases where carcasses were separated from the viscera before examination was possible, the teamster marked them with duplicate tags to enable identification later. Routine examination was for sex, age, whether pregnant and/or lactating, and sex of fetus.

Age determination was by the tooth succession and wear method (Murie, 1951a). No difficulty was experienced in setting off groups I and II in the field, but occasionally there was some doubt about separating groups III and IV. Heads of questionable age were saved and re-examined. Examination for pregnancy was macroscopic in all cases. Pre-

sumably all fetuses conceived during the early-fall breeding season were readily visible. In three instances, uteri bore characteristics of being gravid, but contained no visible fetuses. Possibly the young had been removed by curious workers from two of these before I had a chance to examine them. Both were average-sized for gravid uteri. The other uterus was appreciably smaller than most gravid uteri, and it is possible that the embryo was too small to be readily visible. These cases have been discussed with Harold Watling of Montana State College with the decision that they should be tallied as pregnancies. The mammae were severed for record of lactation. If the fluid was of white, milky color, the animal was listed as "wet"; otherwise, the animal was considered "dry."

Examinations were incomplete on a number of specimens. Sometimes butchers removed the mammae and left them in the snow where they could not be found. Ravens and coyotes destroyed a few female reproductive tracts before examination. Heads of four animals were disposed of before being aged and two marked for rechecking became unavailable. All of these shortcomings were beyond our control and should have introduced no error in sampling the elk slaughter.

1951 Slaughter

Shooting was done almost the same as in the previous season except that the area extended farther west. Of the 476 elk killed between January 2 and 26, 378 were examined for biological data. The sample is probably representative of the kill. Two cow elk accidentally killed at the Mammoth trap on December 10, 1950, and February 4, 1951, are also included in this treatment. Examinations followed the procedure previously used.

MINIMUM BREEDING AGE OF FEMALES

Numerous references in the literature and general opinion of wildlife workers credit the female elk with first breeding in its third year. Specific quantitative records of this are few, however. Rush (1932) states, "From the data gathered from cow elk killed by hunters after the breeding season it is found that *yearling cows do not breed.* About 98% *of the two-year-olds and older,* with the exception of the *extremely old ones,* are pregnant." Mills (1935) found one of five yearlings pregnant. West (1941) observed that cows normally breed first in their third year. Murie (1951a) states, "Normally a cow elk breeds for the first time in the third rutting season after birth, . . . Although a large number of so-called yearling cows have been examined in winter . . . one with calf was never found . . ." His work was mainly with the Jackson Hole herd but included samples from the Yellowstone herd. Specific date (USFS, 1936; Nelson, 1951) from Jackson Hole cover seven yearling females, all barren. Green (1950), who reported on 47 yearling females from Banff National Park, Canada, apparently considered them non-breeders.

Our pregnancy data (Table 1) substantiate the literature. All records for the Yellowstone herd are: age I—37 with none pregnant, age II—44 with 2 (5 per cent) pregnant, and age III—30 with 26 (87 per cent) pregnant. The only other available records of females of age III

or less are from Jackson Hole where 7 cows, age II, were non-pregnant.

TABLE 1.—INCIDENCE OF PREGNANCY, YELLOWSTONE ELK, 1949–1950, 1951

Age Group	1949–1950 No. Spec.	With Fetus No.	With Fetus Per cent
I	21	0	0
II	14	0	0
III	11	8	73
IV+	364	287	79
Unknown II, III or IV+	6	6	100

Age Group	1951 No. Spec.	With Fetus No.	With Fetus Per cent
I	16	0	0
II	25	1	4
III	19	18	95
IV+	240	226	94

Lactation can be considered proof of pregnancy during the preceding year. Many cows, of course, would have "dried up" before mid-winter, as is evidenced by only 25 per cent of 549 females of age IV+ being "wet" during the two recent winters. None of 36 yearlings and only one of 28 two-year-olds was lactating. This strengthens the data as regards non-breeding of calves and only occasional breeding of yearlings.

These records indicate that for practical management purposes, breeding of female elk under two years of age is of minor importance in the Yellowstone herd.

INCIDENCE OF PREGNANCY

Age III and IV+

Quantitative data on pregnancy of Yellowstone elk, age III and IV+, are listed in Table 2 with all available data from other areas. There is considerable variation in pregnancy for the five Yellowstone samples, the spread being 74 to 94 per cent. Rates for Banff show a similar spread. Pregnancy for the composite from Yellowstone (85 per cent of 1,053 animals) shows a highly significant difference from that for Banff—78 per cent of 685. No explanation is offered for this difference.

Lactation records for females of age IV+ were expected to yield supplemental data on this phase. Since animals which had bred at age III would have passed their next birthday before lactation records were obtained, lactation in group IV+ is a result of pregnancy for group III and IV+ of the previous year. Data for Table 3 were grouped by eight-day periods.

Obviously the lactation incidence of group IV in 1951 was so much lower than the pregnancy incidence in combination III, IV for 1949-1950 that it fails to approximate the previous pregnancy incidence. It appears, therefore, that

TABLE 2.—INCIDENCE OF PREGNANCY IN ROCKY MOUNTAIN ELK, AGE III AND IV+

Sample	N. Yel. 1949–50 Kittams	N. Yel. 1951 Kittams, Gaab	N. Yel. 1935 Mills	N. Yel. 1937 West	N. Yel. 1943 Murie	J. Hole 1935–36 Murie	Banff 1943–44 Green	Banff 1944–45 Green	Banff 1945–46 Green	Banff 1946–47 Green	Banff 1947–48 Green	TOTAL
No. Specimens	375	259	129	134	156	334	53	117	198	152	165	2,072
No. Pregnant	295	244	96	122	141	298*	40*	109	149	113	125	1,732
% Pregnant	79	94	74	91	90	89	75**	93	75	74	76	84

* Computed from number of specimens and per cent pregnant (Murie, 1951; Cowan, 1950).
** Given by Cowan (1950) as 76, probably should be 75.

incidence of lactation so late in the season is of little value for determining pregnancy for the previous year.

Age II, III and IV+

Most herd and checking station classifications place all females older than calves in one group. Separation of age II animals is possible only when the jaws can be examined, generally with dead animals and where a technician is available. Since the common grouping of cows includes yearlings, most of which are non-breeders, it is desirable to know the pregnancy rate for cows of all age classes.

TABLE 3.—INCIDENCE OF LACTATION IN FEMALES OF AGE GROUP IV+

Date group	No. specimens	Per cent lactating
1949–50		
Dec. 19–25	56	46
Dec. 26–Jan. 2	99	32
Jan. 3–10	91	20
Jan. 11–18	67	31
1951		
Jan. 3–10	77	16
Jan. 11–18	88	18
Jan. 19–26	69	14

Our samples of cows contained 6 per cent (39/673) yearlings. For them, yearlings reduced the pregnancy rate from 85 to 80 per cent, disregarding the one pregnant yearling.

YOUNG PER FEMALE

Most literature and opinions of workers rate the elk as producing but one young at a time. In the Yellowstone herd Rush (1932) never observed twinning; Mills (1936) found no case of twinning in 96 pregnancies, but received a report of one in the hunting area; West (1937) found one twinning in 122 pregnancies; and Murie (1943) found none in 141.

Caton (1877) observed twins to be "of very rare occurrence" in his captive herd but believed that elk in the wild often produced twins and occasionally triplets. A sample from the Jackson Hole herd (USFS, 1936) gave two cases of twinning in 175 pregnancies. Murie (1951a) refers to two pairs of twins in the total kill of over 500 elk in Jackson Hole and later writes about examining "334 cow elk of breeding age" and finding 89.2 per cent (298) pregnant. Probably, then, the two twinnings were all among 298 pregnancies. For the Roosevelt elk (*C. c. roosevelti*) Schwartz and Mitchell (1945) had no twinning records. In Banff, Alberta, Green (1950) found one twinning in 496 pregnancies. Cowan (1950) probably included this in his comparison of twinning among elk on adequate range to those on overstocked range: "In Banff and Jasper Parks just two sets of twin calves were seen in 4 years whereas warden reports place the percentage of twins in Waterton Park at between 20 and 25 per cent." He considered the difference between "less than 1 per cent" and 25 per cent significant. The high percentage for Waterton greatly exceeds any other available record. Perhaps it is based on calf-at-heel observations. If so, considerable error could result. Murie's (1951a) extensive observations and review of the literature led him to conclude, "Almost invariably the cow elk gives birth to a single calf, though twins occasionally occur."

In our two samples we had one case of twinning, by a female of age IV+, in 537 pregnancies. An apparently authentic record of another twinning was made

by District Ranger Thomas F. Ela during the reduction in 1951. This latter record is not included in our study group, though, because it represents a selected individual.

All usable data collected from the northern Yellowstone herd cover 896 pregnancies with only two twinnings. This indicates that the incidence of twinning is almost certainly below one-half of one per cent and is probably much less than this. All available quantitative records of the Rocky Mountain elk total 1,690 pregnancies with 5 twinnings. For this total number the incidence of twinning is almost certainly below one-third of one per cent and is probably much less than this.

SEX RATIO OF FETUSES

It is assumed that sex ratio is 100 : 100 at the time of conception. Subsequent divergences from an even ratio is significant to an understanding of herd dynamics. Earliest sex records of Yellowstone fetuses were made in December. In Banff first records were in November; in Jackson Hole, in December. Many of the data cannot be separated by months, so all of them are treated together in Table 4.

There is considerable variation in the sex ratio of samples from Yellowstone and elsewhere, with a spread of 88 to 121 males per 100 females (Table 4). None of the three composites, Yellowstone (441 males and 443 females), Banff (243 males and 219 females), and the total for the three areas represented, shows a significant difference from the even ratio.

The records for Yellowstone and other areas indicate that elk fetuses from two to five months old do not deviate from an even sex ratio, the same as that assumed to prevail at conception.

SUMMARY

A quantitative study of reproduction of the largest elk herd in Yellowstone National Park was made. Only prenatal phases of reproduction are considered in this paper. The 8,000 to 12,000 elk in this herd since 1934 has greatly exceeded late-winter grazing capacity and has necessitated intensive control. Data collected from five slaughters in the park and general statements based on observations at other times were used for the following:

1. Limited data (covering 37 calves, 44 yearlings, and 30 two-year-olds) and general statements indicate that female calves do not breed, very few yearlings breed, and most two-year-olds do breed. Meager information on other herds agrees. For practical management purposes, breeding of female elk under two years of age is of minor importance.

2. A pregnancy rate of 85 per cent

TABLE 4.—SEX RATIO OF FETUSES TWO TO FIVE MONTHS OLD

Sample	Yel. Park 1949–50 Kittams	Yel. Park 1951 Kittams, Gaab	Yel. Park 1935 Mills	Yel. Park 1937 West	Yel. Park 1943 Murie	J. Hole 1935–36 Murie	Banff 1944–45 Green	Banff 1945–46 Green	Banff 1946–47 Green	Banff 1947–48 Green	
Months	Dec.-Jan.	Jan.*	Jan.-Feb.	Jan.-Feb.	Jan.	Dec.-Jan.	Nov.-Jan.	Nov.-Jan.	Nov.-Jan.	Nov.-Jan.	TOTAL
No. M. Fetuses	156	116	44	57	68	144	58	66	58	61	828
No. F. Fetuses	141	125	50	65	62	139	48	67	52	52	801
Ratio, M:F	111:100	93:100	88:100	88:100	110:100	104:100	121:100	99:100	112:100	117:100	103:100

* One specimen from Dec. 1950, and one from Feb. 1951.

was found in 1,053 Yellowstone elk which had passed their second birthday. This is greater (highly significant) than the rate found in Banff National Park, Canada. Lactation in mid-winter 1950-1951 was much lower than the pregnancy of the previous year, and was unsatisfactory as an index of previous pregnancy. Yearling females, when included in the "cow" category, reduced the pregnancy rate about five per cent.

3. In 896 pregnancies in the Yellowstone herd, there were two cases of twinning with the remainder being single-fetus pregnancies, indicating that most females bear only one young per year. Data for other herds, 794 pregnancies with three twins and 791 singles, closely agree.

4. The sex ratio of 884 fetuses from Yellowstone was very close to 100 : 100, the assumed sex ratio at conception. The ratios of 462 specimens from Banff and of 1,629 from all areas likewise were not significantly different from an even ratio.

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Accepted for publication July 31, 1952.

BLOOD PARASITES OF THE CANADA GOOSE, *Branta canadensis interior*

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In November, 1950, blood smears were made from 353 Canada geese (*Branta canadensis interior*) at Horseshoe Lake Game Refuge in southern Illinois. The smears were fixed with methyl alcohol and stained with Giemsa's stain containing 0.5% Triton X-30, as suggested by Brooke and Donaldson (1950) to prevent transfer of parasites between blood films when many slides are stained in the same container. The slides were examined under oil immersion objective for a minimum of 10 minutes each. The present paper, which is a contribution from the continuing investigations of Canada geese in Illinois sponsored by the Illinois Natural History Survey, reports the results of this study. For background discussions of the goose population involved, see Hanson and Smith (1950).

Microfilariae and blood protozoa of the genera *Haemoproteus*, *Leucocytozoon* and *Plasmodium* were encountered.

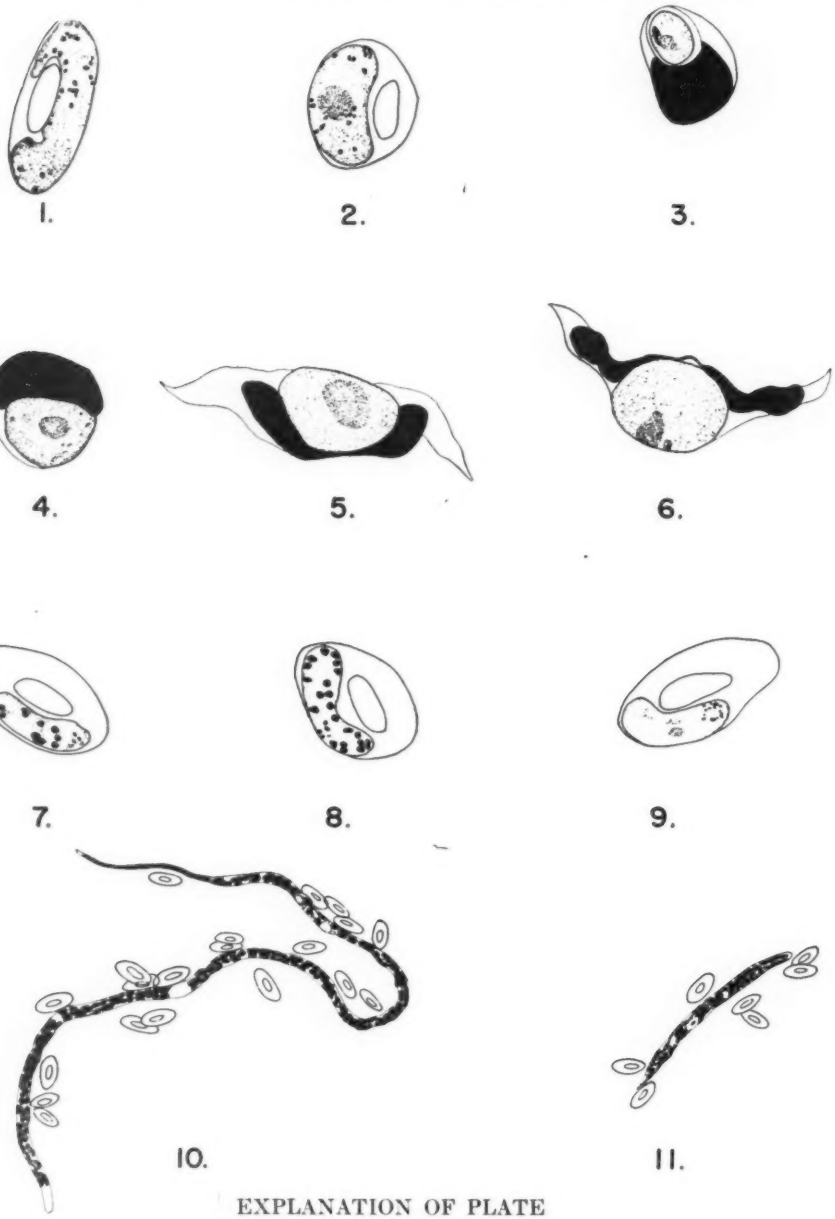
Haemoproteus sp.

Haemoproteus was found in five geese. The mature gametocytes did not enlarge the host erythrocyte, but they did push its nucleus to one side. There was usually a small space between the erythrocyte nucleus and the outer wall of the parasite, but it was not always present. Each gametocyte contained from 16 to more than 30 medium-sized, round, dark brown pigment granules which were usually distributed throughout the cytoplasm with a tendency to be more numerous at the ends. The parasite nuclei were central. Gametocytes are shown in Figures 1-2.

Haemoproteus has been reported from 22 species of Anatidae (Table 1). The scientific names of all hosts in this paper are those given by the American Ornithologists' Union *Check-list of North American birds* (1931 and subsequent supplements) or by Peters' (1931-1938) *Check-list of birds of the world.*

Before deciding to which species the Canada goose form belongs, it is necessary to review the available information on the species which have already been described. Since cross-transmission experiments have not been reported, it is unfortunately necessary to rely only on morphological data. These are sparse; in many cases the presence of a *Haemoproteus* was simply reported without any description.

H. danilewskii Kruse, 1890 was reported by Plimmer (1912, 1915) from three species of ducks. This parasite was originally described from the grey crow, *Corvus cornix*. The name is no longer acceptable for parasites of Anseriformes without proof of transmissibility. Plimmer did not describe the parasites he saw.



EXPLANATION OF PLATE

Blood Parasites of the Canada Goose.

FIGS. 1 and 2. *Haemoproteus* sp. gametocytes.
FIGS. 3 and 4. Young gametocytes of *Leucocytozoon simondi*.
FIG. 5. Microgametocyte of *Leucocytozoon simondi*.
FIG. 6. Macrogametocyte of *Leucocytozoon simondi*.
FIGS. 7 and 8. Segmenters of *Plasmodium* sp.
FIG. 9. Gametocyte of *Plasmodium* sp.
FIG. 10. Large microfilaria. x 450.
FIG. 11. Small microfilaria. x 450.

TABLE 1.—*Haemoproteus* REPORTS FROM WATERFOWL

HOST	*Haemoproteus* SPECIES	REFERENCE
Cygnus columbianus—whistling swan	sp.	Wetmore, 1941
Branta c. canadensis—Canada goose	sp.	Wetmore, 1941
Aix sponsa—wood duck	sp.	Nelson and Gashwiler, 1941
Anas sp.—African duck	sp.	Schwetz, 1931
Anas acuta—pintail duck	sp.	Kowarski *et al.*, 1937
Anas acuta tzitzihoa—American pintail	sp.	Wood and Herman, 1943
Anas boschas—white Pekin duck	sp.	Chernin and Sadun, 1949
Anas carolinensis—green-winged teal	*hermani*	Herman, 1951
Anas (= *Nettion*) *castaneum*—Australian teal	*nettionis*[1]	Johnston and Cleland, 1909
Anas (=*Querquedula*) *discors*—blue-winged teal	sp.[2]	Takos, 1947
Anas platyrhynchos—mallard	*hermani*	Herman, 1951
Anas p. platyrhynchos—common mallard	sp.	Wetmore, 1941; Wood and Herman, 1943
Anas rubripes—black duck	sp.	Herman, 1938a, 1938b; Nelson and Gashwiler, 1941
	anatis	Haiba, 1946
	hermani	Haiba, 1948
Asarcornis scutulata—white-winged duck	sp.	Kowarski *et al.*, 1937
Cairina (= *Anas*) *moschata*—Muscovy duck	sp.	Leger, 1918
Cheniscus (= *Nettapus*) *coromandelianus*—cotton teal	*danilewskii*[3]	Plimmer, 1915
Casarca (=*Tadorna*) *tadornoides*—Australian sheldrake	*danilewskii*[3]	Plimmer, 1912
Sarkidiornis melanota—wattle duck	sp.	Rodhain *et al.*, 1913
Spatula clypeata—shoveller	*hermani*	Herman, 1951
Aythya (=*Fuligula*) *baeri*—Baer's pochard	*danilewskii*[3]	Plimmer, 1912
Aythya (= *Nyroca*) *collaris*—ring-necked duck	sp.	Nelson and Gashwiler, 1941
Aythya (= *Nyroca*) *nyroca*—white-eyed duck	sp.	Kowarski *et al.*, 1937
Netta rufina—rufous-crested duck	sp.	Kowarski *et al.*, 1937

[1] This species was erroneously referred to as *H. nettii* by Cleland and Johnston, 1910.
[2] Unidentified Haemosporidia; only ring states seen.
[3] Plimmer misspells this, "*danilewskyi*."

The *Haemoproteus* species reported by Leger (1918) from *Cairina moschata* was long, with a central nucleus. It contained numerous pigment granules of various sizes, or in the form of four or five baguettes which might extend half the length of the parasite. Around them was a very fine, powdery pigment. The parasitized erythrocytes were either normal or lengthened and thin. Their nuclei and cytoplasm were unchanged.

H. nettionis (Johnston and Cleland, 1909) from *Anas castaneum* was large in relation to the host cell size. Its mature gametocytes displaced the host erythrocyte nucleus laterally and filled its whole cytoplasm except for an area on one side of the nucleus. They contained 13 to 30 pigment granules more or less uniformly distributed through the cytoplasm but with a tendency to be more numerous near the poles. Johnston and Cleland stated that the pigment granules were larger than any they had seen in other Australian birds, but their figures show the granules to be medium-sized, and not even as large as those of *H. columbae* of the pigeon.

The *Haemoproteus* sp. which Rodhain *et al.* (1913) described from *Sarkidiornis melanota* did not enlarge the host erythrocytes. It was rounded, filled with pigment granules, and displaced the host cell nucleus.

The *Haemoproteus* sp. which Herman (1938b) described from *Anas rubripes* did not affect the host cell size, but usually displaced its nucleus to the side. It contained 0-13 (usually 4-6) round or rod-shaped, black pigment granules which were usually polar. Haiba (1946, 1948) found an "identical" form in the same host species in Egypt.* His two papers are both summaries of a thesis presented for the M.V.Sc. degree, based on a study of 1279 Egyptian birds of 22 species. In the 1946 paper he named the form from *A. rubripes*, *H. anatis*; in the 1948 paper, which does not refer to the earlier one, he named it *H. hermani*. This name cannot stand; it is a synonym of *H. anatis* Haiba, 1946.

* *Anas rubripes* is not found wild in Egypt. Haiba did not state whether the black ducks he examined were captive or not.

Kowarski *et al.* (1937) did not describe the parasites which they found, but they figured forms from *Aythya nyroca*, *Netta rufina*, *Anas acuta* and *Asarcornis scutulata*. The mature gametocytes displaced the host cell nuclei laterally in all four hosts and nearly filled the host cells. They contained medium-sized round pigment granules which were distributed more or less throughout the cytoplasm, but with a tendency to be more numerous at the poles. Two microgametocytes from *A. nyroca* contained 28 and about 33 pigment granules; two macrogametocytes contained 31 and 30 granules. Two microgametocytes from *N. rufina* contained 26 and 24 pigment granules; two macrogametocytes contained 24 and 27. Two microgametocytes from *A. acuta* contained 16 and 24 granules; four macrogametocytes, 22, 22, 23, and 24. Two microgametocytes from *A. scutulata* contained 52 and 60 granules; two macrogametocytes, 41 and 60. These counts were made from their figures; it is impossible to say whether different numbers of granules might have been present in other individuals.

Wetmore (1941) stated that three types of *Haemoproteus* were present in *Anas p. platyrhynchos*, but she described only the most frequent one. The gametocytes displaced the host cell nucleus laterally. They were usually in contact with the host cell periphery, but often did not touch its nucleus. They contained 8 to 26 (mean, 17.6) pigment granules. Wetmore stated that this form was shorter than that described by Herman from the black duck and contained more pigment granules, but Herman (1951) considered it to be the same species.

The other investigators did not describe the parasites which they reported. Herman (1951), however, considers that the forms reported by Nelson and Gashwiler (1941) and Wood and Herman (1943) were *H. hermani*.

The form described by Leger (1918) from *Cairina moschata* seems to be different from the others. However, except for differences in the numbers of pigment granules, the forms reported by Johnston and Cleland (1909), Rodhain *et al.* (1913), Kowarski *et al.* (1937), Herman (1938b) and Wetmore (1941) were quite similar. The form reported in the present paper from *Branta canadensis interior* is also similar to these. If future cross-transmission studies confirm the opinion that they all belong to the same species, the correct name for all the forms except that described by Leger (1918) would be *Haemoproteus nettionis*, (Johnston and Cleland, 1909) Coatney, 1936. If this is the case, then *H. anatis* Haiba, 1946 would be a synonym of *H. nettionis*. However, for the present it is probably advisable to suspend judgment.

Leucocytozoon simondi Mathis and Leger, 1910

Leucocytozoon was found in 32 geese. The *Leucocytozoon* macrogametocytes stained a rather dark blue and had compact red nuclei; the microgametocytes were very pale blue, and had diffuse, pale pink nuclei. The host cells of the mature gametocytes were elongate, with pale cytoplasmic "horns" extending out beyond the very long, thin host cell nuclei. The microgametocytes were much more delicate and subject to distortion than the macrogametocytes, a circumstance which has

already been remarked by Mathis and Leger (1910) in *L. simondi* from the teal duck, *Anas crecca*. In younger gametocytes, the host cell nucleus was not so elongated. Very young forms were seen in lymphocytes, in which they simply formed a notch in the nucleus. A good deal of controversy has existed as to the type of cell parasitized by *Leucocytozoon*, but no evidence was seen in the Canada goose that cells other than leucocytes are parasitized. The cells which contained mature gametocytes were so distorted that it was impossible to identify them, but the cells which contained very young forms were clearly lymphocytes or monocytes. Gametocytes and young forms are shown in Figs. 3-6.

Leucocytozoon has been reported from 24 species of Anatidae (Table 2).

L. simondi Mathis and Leger, 1910 from *Anas crecca* was the first species named from the Anseriformes. Wickware (1915) gave the name, *L. anatis*, to the parasite in other ducks and this name was used by O'Roke in his papers and by Hartman (1929) and Nelson and Gashwiler (1941). However, Herman (1938c) believed that *L. anatis* was a synonym of *L. simondi*, and this opinion has been generally accepted.

L. anseris was named as a new species by Knuth and Magdeburg (1922) from the domestic goose in Europe, and this name was also used by Ivanić (1937). However, Herman (1944), in his review of the blood protozoa of North American birds, considered the forms found in North American wild geese to be *L. simondi*. Likewise, while Herman (1938a, 1938c), Huff (1939, 1942), Wetmore (1941) and Wood and Herman (1943) did not assign specific names to the

TABLE 2.—*Leucocytozoon* REPORTS FROM WATERFOWL

HOST SPECIES	REFERENCE
Anser anser—domestic goose	Knuth and Magdeburg, 1922; Ivanić, 1937; Jarinova, 1937; Wickware, 1941
Anser anser (=*ferus*)—gray-lag goose	França, 1912
Anser albifrons frontalis[1]—white-fronted goose	Wood and Herman, 1943
Branta canadensis—Canada goose	Fallis, 1951
Branta c. canadensis—Canada goose	Herman, 1938a
Branta canadensis interior—Canada goose	O'Roke, 1943
Branta canadensis minima—cackling goose	Wood and Herman, 1943
Aix sponsa—wood duck	Nelson and Gashwiler, 1941
Anas (=*Dafila*) *acuta tzitzihoa*—American pintail	O'Roke, 1934, 1943; Wetmore, 1941; Wood and Herman, 1943; Herman, 1951
Anas boschas—domestic duck	França, 1912
Anas (=*Nettion*) *carolinensis*—green-winged teal	Nelson and Gashwiler, 1941
Anas (=*Querquedula*) *crecca*—teal duck	Mathis and Leger, 1910
Anas (=*Querquedula*) *discors*—blue-winged teal	Herman, 1938c; O'Roke, 1943
Anas (=*Eunetta*) *falcata*—falcated teal	Plimmer, 1915
Anas platyrhynchos—mallard	Herman, 1951; Fallis, 1951
Anas p. platyrhynchos—common mallard	O'Roke, 1934, 1943; Wetmore, 1941; Huff, 1942; Wood and Herman, 1943
Anas rubripes—black duck	O'Roke, 1934, 1943; Herman, 1938a, 1938c; Nelson and Gashwiler, 1941; Fallis, 1951
"Duck"	Wickware, 1915; Hartman, 1929; O'Roke, 1930, 1931a, 1931b, 1934
"Domestic duck"	Chernin and Sadun, 1948, 1949; Goldsby, 1951
Mareca americana—baldpate	Wetmore, 1941; Herman, 1951
Spatula clypeata—shoveller	O'Roke, 1943; Herman, 1951
Aythya (=*Nyroca*) *affinis*—lesser scaup duck	O'Roke, 1943; Fallis, 1951
Aythya (=*Nyroca*) *americana*—redhead	O'Roke, 1943; Wood and Herman, 1943
Aythya (=*Nyroca*) *collaris*—ring-necked duck	O'Roke, 1934, 1943; Nelson and Gashwiler, 1941
Aythya (=*Nyroca*) *marila*—scaup duck	Plimmer, 1912; O'Roke, 1943; Fallis, 1951
Aythya (=*Nyroca*) *valisineria*—canvas-back	O'Roke, 1934, 1943
Bucephala (=*Glaucionetta*) *clangula*—American golden-eye	Nelson and Gashwiler, 1941; O'Roke, 1943
Clangula hyemalis—old-squaw duck	Fallis, 1951
Lophodytes cucullatus—hooded merganser	Nelson and Gashwiler, 1941
Mergus merganser americanus—American merganser	Nelson and Gashwiler, 1941; O'Roke, 1943; Fallis, 1951
Mergus serrator—red-breasted merganser	Herman, 1938c; Huff, 1939; O'Roke, 1943; Wood and Herman, 1943

[1] Wood and Herman (1943) listed the host species as *Anser a. albifrons*, but it is now considered that the North American subspecies is *A. albifrons frontalis*.

Leucocytozoon which they described, Herman (1944) assigned them all to *L. simondi*. França (1912) stated that the form he saw in *Anas boschas* was identical with *L. simondi*, but that the one he saw in *Anser anser* was different. He did not describe it, however.

Goldsby (1951) reported *L. smithi* from ducks in North Dakota, but this was probably an error, since she also reported it from turkeys at the same time. *L. smithi* is the turkey species.

It is considered justifiable to assign all members of the genus *Leucocytozoon* so far reported from the Anseriformes to the single species, *L. simondi*, at least until future cross-transmission studies prove this opinion wrong. No morphological evidence appears to contradict this view. Hence, the form from *Branta c. interior* is considered to be *L. simondi*.

Leucocytozoon simondi is known to be pathogenic. It is responsible for heavy mortality among young ducks, both domestic and wild, and is also pathogenic for the domestic goose. Its pathogenicity for the Canada goose is unknown.

Plasmodium sp.

Plasmodium was found in a single adult bird. Ring stages, presegmenters, segmenters and a young gametocyte were seen (Figs. 7-9). They usually lie along one side of the nucleus, although sometimes they extended below it. The segmenters were elongate. The parasites did not displace the nucleus or enlarge the host erythrocyte. A compact mass of brownish-yellow pigment granules was present at one end of the presegmenters and segmenters. From 6 to over 20 merozoites were counted in the segmenters; it is possible that division had not been completed in those with few merozoites. The parasites did not touch the nucleus, and usually did not extend to the margin of the host erythrocyte.

Plasmodium has been reported from eight species of Anatidae (Table 3).

TABLE 3.—*Plasmodium* REPORTS FROM WATERFOWL

HOST	*Plasmodium* SPECIES	REFERENCE
Chenopis atrata—black swan	*biziurae*	Cleland, 1915
Cygnus melanocoriphus—swan	*praecox*	Scott, 1928
Anas (=Dafila) acuta tzitzihoa—pintail	*relictum*	Herman, 1951
	sp.	Herman, 1951
Anas (=Querquedula) cyanoptera—cinnamon teal	*relictum*	Herman, 1951
Anas (=Eunetta) falcata—falcated duck	*praecox*	Plimmer, 1915
Anas poecilorhyncha—duck	sp.	Laird, 1950
Duck	*praecox*	von Prowazek, 1920
Arctonetta fischeri—spectacled eider duck	*circumflexum*	Savage and McTavish, 1951
Biziura lobata—musk duck	*biziurae*	Gilruth, Sweet and Dodd, 1910

In addition, the domestic duck has been infected experimentally with *P. relictum* by Wolfson (1939), *P. cathemerium* by Wolfson (1938, 1940a), *P. elongatum* by Wolfson (1940b), *P. lophurae* by Wolfson (1940b) and Fallis (1946), and *P. circumflexum* by Fallis (1946) and Manwell (1951). The wild goose has been infected experimentally with *Plasmodium* sp. from the penguin, *Spheniscus demersus* by Rodhain (1937), and the domestic goose has been infected experimentally with *P. gallinaceum* by Brumpt (1936a,b).

P. praecox is now considered a synonym of *P. relictum* (*cf.* Hewitt, 1940), while Herman (1951) considers *P. biziurae* also to be a synonym of *P. relictum*. Hence the only species of *Plasmodium* so far reported from the Anseriformes are *P. relictum*, *P. circumflexum* and the *Plasmodium* sp. re-

ported by Herman (1951). This form had elongate gametocytes.

The *Plasmodium* described in the present paper strongly resembled *P. circumflexum*, and probably was this species. However, without a study of experimental infections, identification could not be made. Dr. Reginald D. Manwell, who also examined the slide, agreed in this opinion. This appears to be the first report of *Plasmodium* in naturally infected geese.

MICROFILARIAE

Microfilariae were found in 4 of the geese. A long, thin form was found in one goose, and a short, stout form in three.

Only two specimens of the long, thin microfilaria were seen (Fig. 10). They were not sheathed, and were 323 and 341 microns long, respectively. From the anterior end to the first nucleus was 10 and 9 microns, respectively; from the anterior end to the beginning of the nerve ring, 67 and 75 microns; from the beginning of the nerve ring to the beginning of the excretory cell, 35 and 38 microns; and from the end of the last nucleus to the tip of the tail, 1 micron. The microfilariae were from 4 to 4.4 microns in width.

The short microfilariae were also unsheathed (Fig. 11). Fifteen individuals ranged in length from 50 to 82 microns, with a mean of 65 microns. The distance from the anterior end to the first nucleus averaged 0.6 microns (range, 0 to 1.3 microns). The distance from the anterior end to the nerve ring averaged 20 microns (range, 16 to 27 microns). The distance from the beginning of the nerve ring to the beginning of the excretory cell averaged 16 microns (range, 11 to 19 microns). The microfilariae ranged in width from 4 to 4.4 microns. Striations were visible, particularly at the posterior end, in all but two of the microfilariae.

Microfilariae have been reported from 13 species of Anatidae (Table 4).

TABLE 4.—MICROFILARIAE REPORTED FROM WATERFOWL

HOST	REFERENCE
Anser anser—domestic goose	Wickware, 1941
Branta canadensis—Canada goose	Wickware, 1941
Aix sponsa—wood duck	Nelson and Gashwiler, 1941
Anas (= Dafila) acuta tzitzihoa—American pintail	Wetmore, 1941
Anas carolinensis—green-winged teal	Nelson and Gashwiler, 1941; Herman, 1951
Anas platyrhynchos—mallard	Herman, 1951
Anas p. platyrhynchos—common mallard	Wetmore, 1941; Wood and Herman, 1943
Anas rubripes—black duck	Nelson and Gashwiler, 1941
Mareca americana—baldpate	Wetmore, 1941; Herman 1951
"Domestic duck"	Chernin and Sadun, 1949
"Wild duck"	Torrey, Thorp and Graham, 1934; Beaudette, 1936
Aythya (= Nyroca) affinis—lesser scaup duck	Wetmore, 1941
Aythya (= Nyroca) collaris—ring-necked duck	Nelson and Gashwiler, 1941
Aythya (= Nyroca) valisineria—canvas-back	Wetmore, 1941
Lophodytes cucullatus—hooded merganser	Nelson and Gashwiler, 1941
Mergus serrator—red-breasted merganser	Wood and Herman, 1943

Several types of microfilaria have been reported from the Anseriformes, but in some cases descriptions are either lacking or so brief as to make comparisons difficult. A sheathed form in *Aix sponsa* was called "Type C" by Nelson and Gashwiler (1941). It measured 125 by 7 microns, and its sheath extended 12 microns beyond its posterior end. Nelson and Gashwiler thought it might be the same as the form reported by Beaudette (1936) from the wild duck.

Several unsheathed forms have been described. The smallest, which measured 45 to 65 by 4 to 6 microns, was found by

Nelson and Gashwiler (1941) in *Aix sponsa, Anas carolinensis, Anas rubripes, Aythya collaris* and *Lophodytes cucullatus*. It had a short, narrowed, characteristically curved or slightly twisted tail. Cross striations, particularly at the posterior end, were seen in some slides. Nelson and Gashwiler called this form "Type A" and considered it to be similar to the microfilariae figured by Torrey, Thorp and Graham (1934).

Another unsheathed microfilaria which measured 115 to 135 by 4 microns was reported by Nelson and Gashwiler (1941) from *Aix sponsa*. They called it "Type B."

Wetmore (1941) described two unsheathed forms from *Anas p. platyrhynchos*. One measured 116 to 175 by 4.2 to 5.6 microns (mean, 150 by 4.9 microns), had blunt anterior and posterior ends and a wavy shape. The other measured 90 to 109 by 4.2 to 5.6 microns (mean, 98 by 5.7 microns), had a blunt anterior end and a pointed posterior end. Wood and Herman (1943) reported an unsheathed form which measured 104 by 4 microns from this same host.

The largest unsheathed microfilaria, which measured 296 by 6 microns, was reported by Wood and Herman (1943) from *Mergus serrator*.

It is quite possible that the short microfilaria from the Canada geese observed in the present study may have been Nelson and Gashwiler's Type A. The large form from the Canada goose is somewhat longer than the microfilaria reported from the merganser by Wood and Herman, but in the absence of morphological data it is impossible to make a comparison.

Relation of Age to Parasite Incidence

There were 76 juveniles (age, 5 to 7 months), 112 "yearlings" (age, 17 to 19 months), and 165 adults (age, 29 months or more) among the 353 Canada geese examined. The ages of the birds were determined by the method described by Hanson (1949). *Leucocytozoon simondi* was found in 21 (27.6%) of the juveniles, 6 (5.4%) of the yearlings, and 5 (3.0%) of the adults. *Haemoproteus* sp. was found in none of the juveniles, 1 (0.9%) of the yearlings, and 4 (2.4%) of the adults. Microfilariae were found in 1 (1.3%) juvenile, 1 (0.9%) yearling, and 2 (1.2%) adults. *Plasmodium* sp. was found in 1 (0.6%) adult. Thus the incidence of *L. simondi* was much higher in the juveniles than in the older birds. The situation was entirely different for *Haemoproteus* sp. This parasite was found in about the same percentage of adults as *L. simondi*, but was not found in any juveniles. Not enough microfilariae and *Plasmodium* were found to draw any valid conclusion on age incidence.

Information on the relation of age to incidence of blood parasites in wild birds has been given by Herman (1938a), Nelson and Gashwiler (1941) and Borg (1949). Only Nelson and Gashwiler gave information on the Anseriformes. In *Anas rubripes* they found *Leucocytozoon simondi* in 87% of 24 adults and 100% of 5 ducklings 3-7 weeks old, and *Haemoproteus* sp. in 8% of the adults and 80% of the ducklings. In *Aix sponsa* they found *L. simondi* in 55% of 18 adults and 64% of 53 juveniles, and *Haemoproteus* sp. in 33% of the adults and 83% of the juveniles.

Herman (1938a) reported that

Haemoproteus sp. was present in 50% of 81 adult and 20% of 39 juvenile chipping sparrows (*Spizella passerina*).

Borg (1949) found *Leucocytozoon* sp. in 100% of 18 adult and 80% of 25 juvenile capercaillie (*Tetrao urogallus*), 40% of 15 adult and 22% of 9 juvenile black grouse (*Lyrurus tetrix*), and 80% of 15 adult and 36% of 22 juvenile willow ptarmigan (*Lagopus lagopus*) in Sweden. He also found *Haemoproteus* sp. in 28% of the adult and 32% of the juvenile capercaillies, 13% of the adult and 56% of the juvenile black grouse, and 13% of the adult and 5% of the juvenile willow ptarmigan.

The markedly higher incidence of *Leucocytozoon* in juvenile than in yearling or adult Canada geese was not observed in the other birds parasitized with this genus. A higher incidence of *Haemoproteus* in adults than in juveniles was found in the Canada goose, chipping sparrow, and willow ptarmigan. On the other hand a lower incidence of this genus was found in adults than in juveniles in the black duck, wood duck, and black grouse.

These differences might be accounted for by differences in the habits of the vectors, but so little is known about the vectors of these protozoa that it is useless to speculate further.

It should be pointed out that all the geese examined in the present study were apparently healthy individuals which had made the long flight from their north Canadian breeding grounds. They were thus carriers and not clinically affected cases. A study of these parasites among the "downies" and older birds in the breeding grounds should be carried out. Information is needed on their incidence, mode of transmission and pathogenicity, particularly for young birds.

True Incidence of Blood Parasites

The incidences of blood parasites given in this paper are those observed when each slide was searched for ten minutes under the oil immersion objective. This time is more or less standard in such blood surveys. These figures, however, cannot be taken to indicate the true incidences of the parasites in the geese. In the five birds in which *Haemoproteus* was found, a single parasite was found during the ten-minute searching period in four birds, while in one bird, two parasites were found in that time. In the 32 geese in which *Leucocytozoon* was found, a single parasite was found during this searching period in 21 birds; in 4 birds two parasites were seen, and in four other birds three parasites were seen during this period. In the goose in which *Plasmodium* was found, two parasites were seen during the ten-minute searching period. In the four birds in which microfilariae were found, a single parasite was found in three, and two parasites in one smear. Thus, if a five-minute searching period had been employed it might have been expected that *Haemoproteus* would have been found in 3, *Leucocytozoon* in 18 or 19, *Plasmodium* in 1, and microfilariae in 2 or 3 birds.

In order to obtain some idea of the percentage of leucocytes which would have to be parasitized in order for a *Leucocytozoon* infection to be discovered in them, counts were made in ten birds of the leucocytes encountered in the ten-minute searching period. From 37 to 110 neutrophiles (mean, 64.7), 37 to

93 lymphocytes (mean, 59.2), 2 to 11 monocytes (mean, 7.5), and 0 to 4 eosinophiles (mean, 1.0) were found during this time. The total numbers of leucocytes varied from 107 to 198, with a mean of 132.4.

The fact that the true incidences of these parasites is probably much higher than indicated by the figures recorded here is suggested by the following experience. The entire smears from the four geese in which microfilariae had been discovered were later searched under a lower power (188 diameters) of the microscope. A single *Leucocytozoon* gametocyte had been found previously in one of the smears; 5 gametocytes were found in this smear under low power. In two of the other three smears, 1 and 6 *Leucocytozoon* gametocytes, respectively, were found. The latter smear was a large one, covering most of the slide, and took over half an hour to cover even under low power. *Leucocytozoon* is rather prominent, but it is nevertheless unlikely that all the gametocytes were seen under low power, since they would be easy to miss. *Haemoproteus* and *Plasmodium* would be even more difficult to see with this magnification. However, the fact that *Leucocytozoon* was seen in two out of three slides which had previously been recorded as negative suggests that its true incidence is much higher than the figures indicate.

SUMMARY

In a study of blood smears from 353 Canada geese (*Branta canadensis interior*) collected at Horseshoe Lake Game Refuge, Illinois, *Leucocytozoon simondi* was found in 32 (9.1%), *Haemoproteus* sp. in 5 (1.4%), *Plasmodium* sp. (probably *P. circumflexum*) in 1 (0.3%) and microfilariae in 4 (1.1%). Two types of unsheathed microfilaria were found, one 65 and the other 332 microns long. *Leucocytozoon* was found in 27.6% of 76 juvenile geese, 5.4% of 112 yearlings, and 3.0% of 165 adults. *Haemoproteus* was found in no juveniles, 0.9% of the yearlings, and 2.4% of the adults. Microfilariae were found in 1.3% of the juveniles, 0.9% of the yearlings, and 1.2% of the adults.

Haemoproteus hermani Haiba, 1948 is a synonym of *H. anatis* Haiba, 1946.

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Accepted for publication January 21, 1952.

INTESTINAL MORPHOLOGY OF GALLINACEOUS BIRDS IN RELATION TO FOOD HABITS

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It is well known that various species of grouse can thrive on a winter diet of buds, catkins, and conifer needles that would not support a quail for a week. Why this should be so has not been determined, to my knowledge. In pursuit of a possible explanation of differential digestive abilities I started some years ago casually inspecting the alimentary tracts of various gallinaceous birds. Gross differences in the relative dimensions of intestines and caeca were noted, the browsing grouse having appreciably longer digestive tracts, especially caeca, than the quails, partridges, pheasants and turkeys which generally depend on somewhat higher quality food in the winter diet. A cursory survey of the ornithological literature yielded some data on galliform intestinal morphology (Bump, *et al*, 1947, for ruffed grouse; Gross, 1928, for heath hen) but apparently no comparative survey of galliforms had been made. Accordingly, over a period of time, samples of most North American galliforms were collected and intestinal tracts measured; the results are here summarized. It is not claimed that these observations completely answer the question posed above, but they undoubtedly have some bearing on the matter. At least they suggest a likely avenue of future research.

I am indebted to a number of colleagues for assistance in assembling materials, particularly Frank A. Pitelka of the Museum of Vertebrate Zoology, Frederick and Frances Hamerstrom of the Wisconsin Conservation Department, Robert A. McCabe of the University of Wisconsin, Ian McT. Cowan of the University of British Columbia, and Gordon W. Gullion of the Nevada Fish and Game Department.

Intestinal Measurements

Intestinal measurements were obtained from 107 specimens, representing 20 species of galliforms native or introduced in North America. Entrails were removed from each bird and the mesenteries cut with scissors or scalpel, permitting the intestines and caeca to be laid out straight, without loops or convolutions but at the same time without undue stretching (Fig. 4). Measurements taken were: (1) *small intestine*, including duodenum, from gizzard to junction of the caeca: (2) *caecum*, from junction with small intestine to tip (usually only one caecum was measured), and (3) *large intestine*, from caecal junction to lip of vent, including cloaca. Prior to dissection each specimen was weighed. Results both of dissection and the taking of measurements on such soft and extensible materials are subject to considerable variability according to techniques used. Every effort was made to achieve uniformity in method.

All data obtained in the study are summarized in Table 1. For most species represented by only one to six

TABLE 1.—SUMMARIZED DATA ON BODY WEIGHTS AND INTESTINAL MEASUREMENTS OF 20 SPECIES OF GALLINACEOUS BIRDS NATIVE OR INTRODUCED IN NORTH AMERICA

Species	Specimens	Locality	Weight (gms.)	Intestinal measurements (cm.) Large intestine	Caeca	Small intestine
FAMILY TETRAONIDAE						
Willow ptarmigan (*Lagopus lagopus*)	5♂, 1♀	Near Point Barrow, Alaska	525(449–589)	12.5(11–14)	47(40–52)	91(80–98)
Rock ptarmigan (*Lagopus mutus*)	1♂	Chandler Lake, Alaska	502	11	47	104
Spruce grouse (*Canachites canadensis*)	1♀	Betiles, Alaska	576	11	40	105
Ruffed grouse (*Bonasa umbellus*)	2♀	Plainfield, Wisconsin	569(566–572)	11.3(11–11.5)	40(35–45)	84(80–88)
Sharp-tailed grouse (*Pediocetes phasianellus*)	4♂	Plainfield, Wisconsin	850	14.5(14–15)	49(43–52)	121(111–126)
(Sharp-tail x prairie chicken hybrid)	1♀	Plainfield, Wisconsin	898	14	47	119
Prairie chicken	3♂	Plainfield, Wisconsin	1120(1076–1183)	14(13–15)	45(35–53)	117(101–131)
(*Tympanuchus cupido*)	3♀	Plainfield, Wisconsin	915(842–989)	14(13–15.5)	41(36–49)	116(110–126)
Sooty grouse (*Dendragapus fuliginosus*)	2♂	Hayfork, California	1250(1205–1295)	18(17–19)	50(45–55)	120(119–121)
[1]Sage grouse (*Centrocercus urophasianus*)	3♀	Susanville, California	1427	13.3(13–13.5)	73(68–79)	135(127–142)
Capercaillie (*Tetrao urogallus*)	1♂	Wisconsin (imported from Norway)	2500	18	52	159
FAMILY PHASIANIDAE						
Bobwhite (*Colinus virginianus*)	1♂, 1♀	Madison, Wisconsin	185	8.3(8–8.5)	14(13.5–15)	62(61–63)
Scaled quail (*Callipepla squamata*)	1♂, 1♀	Ramos, Chihuahua	175(171–180)	9.5(9–10)	10.5(9.5–11.5)	59(57.5–60)
Gambel quail (*Lophortyx gambelii*)	1♂, 1♀	Las Vegas, Nevada	188(184–191)	8.5	11.3(11–11.5)	81(80–82)
California quail (*Lophortyx californica californica*)	15♂, 13♀	Shandon, San Luis Obispo Co., California	173±2(161–198)	8.9±.1(8–9.5)	13.9±.2(12–15)	77.1±1.2(63–86)
(*Lophortyx californica brunnescens*)	10♂ 7♀	Marin and Santa Cruz counties, California	192±3(167–209)	9.0±.3(8–9.5)	16.5±.4(15–18)	85.7±1.0(78–93)
Mountain quail (*Oreortyx picta*)	2♂, 3♀	Pinecrest and Clear Lake, California	250	11.5(10.5–12.5)	17.5(16–18.5)	76.5(70–81)
Montezuma quail (*Cyrtonyx montezumae*)	1♂	Colonia Pacheco, Chihuahua	186	7.5	11.5	46
Hungarian partridge (*Perdix perdix*)	2♂	Plainfield, Wisconsin	395	8.3(8–8.5)	14.5(14–15)	59(58–60)
Chukar partridge (*Alectoris graeca*)	1♂, 1♀	Wisconsin State Game Farm	576(562–590)	8.5	19(17.5–20.5)	77.5(76–79)
Ring-necked pheasant (*Phasianus colchicus*)	15♂	Woodland, California	1270±27(1142–1416)	10.6±.1(10–11.3)	19.8±.6(16.3–25)	101.2±1.9(91–120)
	2♀	Woodland, California	1070	10	18.5(17.5–19.5)	94(91–96)
FAMILY MELEAGRIDIDAE						
Wild turkey (*Meleagris gallopavo*)	2♂	Colonia Pacheco, Chihuahua	7325(7100–7550)	20	42(41–43)	224(223–225)

[1] Data on the sage grose were obtained after this paper went to press and are not plotted on the graphs Figs. (1-3)

specimens, weights and measurements are expressed as simple arithmetic means, with maximum and minimum figures shown in parentheses. Larger samples were obtained of males of the ring-necked pheasant and of two subspecies of California quail, and in these cases means are listed with their standard errors.

Careful scrutiny of measurements obtained from different age groups showed no obvious differences between old and young, so all age groups within a species are averaged together. Likewise no sexual differences were evident except where marked disparity in body size existed, as for example in pheasants and prairie chickens. Only in these species are the sexes averaged and listed separately. Slight sexual differences in intestinal lengths of ring-doves (females having longer intestines), as reported by Riddle and Flemion (1928), are not indicated in galliforms.

For purposes of simplicity I shall refer henceforth to members of the grouse family Tetraonidae as "browsing" species and to quails, partridges, pheasants and turkeys of the families Phasianidae and Meleagrididae as "seed-eating" species. It is recognized, of course, that grouse eat many fruits, insects and other concentrated foods at times, and that many of the "seed-eaters" consume green foods and even some buds on occasion. But in general, the capacity to live for long periods on winter diet exclusively of browse is well developed in all the grouse and but poorly so in the other North American galliforms.

COMPARATIVE ANATOMY OF INTESTINAL TRACTS

Figures 1, 2 and 3 show, respectively, the mean measurements of caeca, small intestines and large intestines of all species examined, plotted against mean body weights. Semi-log plotting paper was used to condense vertically the spread of weight classes of the birds which varied in size from quail to wild turkeys. In reading the curves it should be kept in mind that the vertical scale (body weight) is logarithmic and that the trend lines are thereby distorted in shape.

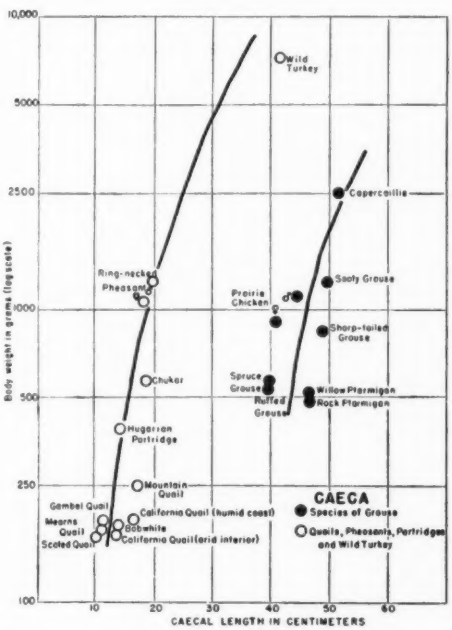

FIG. 1. A comparison of caecal lengths in species of "browsing" grouse of the family Tetraonidae and "seed-eating" quails, partridges, pheasants and turkeys of the families Phasianidae and Meleagrididae.

The most marked difference between the "browsing" grouse and the "seed-eating" quails, partridges, pheasants and turkeys is seen in the relative development of the caeca. As a group, the browsers have caeca considerably

[1] Data on the sage grouse were obtained after this paper went to press and are not plotted on the graphs Figs. (1-3)

over twice as long, per unit body weight, as seed eaters. Thus grouse in the 500-gram weight class (ruffed and spruce grouse, and ptarmigans) have caeca of about 44 cm. whereas chukar and Hungarian partridges, of like size, have caeca averaging nearer 17 cm. A wild turkey, which takes some greens but is essentially a seed-eater, has shorter caeca than a ptarmigan only one-fourteenth its size. Caecal length seems to be proportional to the amount of coarse, low-quality food in the winter diet.

One might ask if length is a dependable or stable characteristic of such a distensible organ as the caecum. It is possible that caecal length changes somewhat with the amount of food contained. Yet even if true, this would not seem to affect greatly the basic comparisons made here. Actually, the differences noted in caecal length may grossly minimize the real differences in food-holding capacity, for the caeca of grouse are notably larger in diameter than those of seed-eating species.

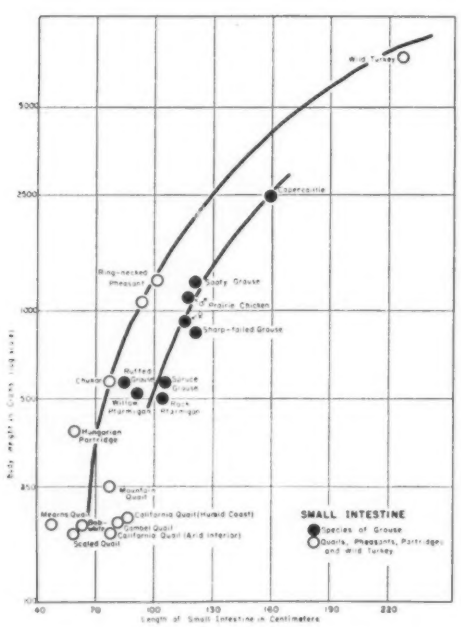

FIG. 2. Comparison of lengths of small intestine in "browsing" and "seed-eating" galliforms.

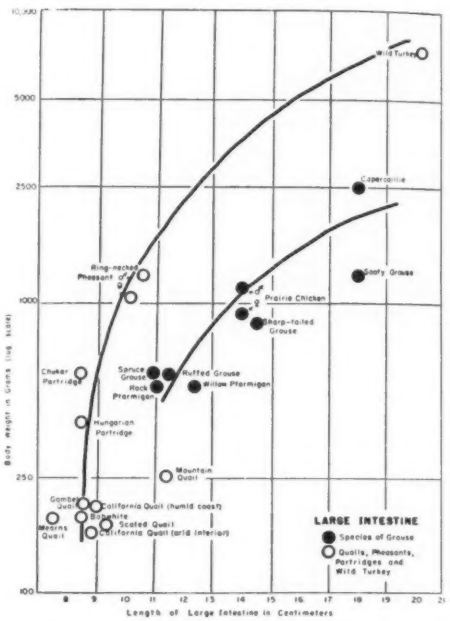

FIG. 3. Comparison of lengths of large intestine in "browsing" and "seed-eating" galliforms.

To a much less marked degree, the relationship noted for the caeca applies also to lengths of small and large intestines, as can be seen in Figures 2 and 3. Grouse do have slightly longer intestines than seed-eating species, but the magnitude of the difference is considerably less than in the case of the caeca. When all my data are summarized collectively, the "average" grouse is found to exceed the "average" seed-eating galliform by 30 per cent in length of large intestine and 28 per cent in length of small intestine, but by 136 per cent in caecal length.

SUBSPECIFIC DIFFERENCES IN CALIFORNIA QUAIL

When enough data were accumulated to show clearly the above relationships, I began to wonder if there might exist differences in intestinal morphology between segments of a given species locally dependent upon different types of food. The California quail was a likely subject of study, since one race (*Lophortyx californica brunnescens*) living along the humid northern coast of California eats considerably more green food than the race (*L. c. californica*) of the arid interior valleys. All California quail eat greens in winter and the seeds of such plants as filaree, bur clover, turkey-mullein, etc., in the dry season, but the *proportion* of greens in the diet is materially higher in coastal populations, as can be seen by comparing data on food habits obtained by Sumner (1935) for the coast and Glading, *et al* (1940) for the interior. Likewise it is an accepted fact among livestock men that green forage produced on the leached soil of the humid coast is materially lower in nutritive value than the forbs and grasses that sprout and flower each winter in the arid foothills of the interior. There was reason to suspect that the coast quail might have to eat much more green food than interior birds in order to obtain the same nourishment. Consequently during the 1951 shooting season I collected for dissection 17 specimens of *L. c. brunnescens* from the coastal areas of Marin and Santa Cruz counties and 28 *L. c. californica* from arid northeastern San Luis Obispo County, near Shandon. Intestinal measurements were taken of all specimens, as described above, and differences noted were subjected to statistical evaluation of significance.

As shown in Table 1, and in Figures 4 and 5, birds of the race *brunnescens* proved to have 19 per cent longer caeca and 11 per cent longer small intestines than their relatives of the race *californica*, and these differences are highly significant ($d/\sigma_d = 5.8$ for caecal measurements and 5.5 for small intestines). Large intestines were not significantly different. Part of the difference in caecal and small intestine length would be accounted for by the size difference in the races, *brunnescens* averaging 19 grams heavier than *californica*. Yet judging from the slope of the curves in Figures 1 and 2, the expected increase in caecal and small intestine length with a 19-gram increase in body weight would be only a small fraction of the observed increase, hence it seems safe to interpret the differences as adaptations to food habits.

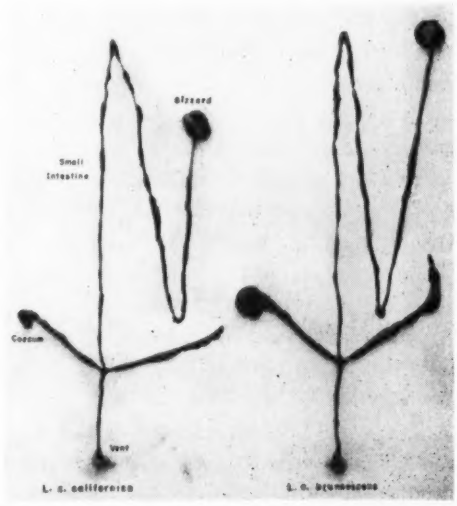

FIG. 4. Intestines of a California quail taken in the arid interior (left) and of a specimen from the humid coast (right), showing difference in caecal development and in length of small intestine.

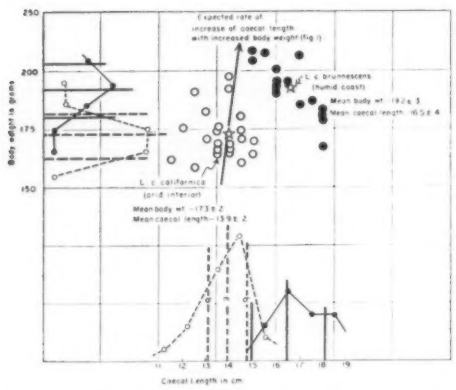
Expected rate of increase of caecal length with increased body weight (fig. 1)
L. c. brunnescens (humid coast)
Mean body wt. 192 ± 3
Mean caecal length 165 ± 4
L. c. californica (arid interior)
Mean body wt. 173 ± 2
Mean caecal length 159 ± 2
Body weight in grams
250
200
175
150
Caecal Length in cm.

FIG. 5. Caecal lengths plotted against body weights of 28 California quail from the arid interior (*L. c. californica*) and of 17 specimens from the humid coast (*L. c. brunnescens*). Means and standard deviations of each sample are indicated on the frequency curves.

In short, coastal populations of California quail seem to be geared internally to a diet containing much bulky green material whereas interior populations more nearly resemble true "seed-eaters" in actual food habits and in intestinal morphology. Gross morphologic differences observed between families of galliforms are therefore projected as minor modifications even between populations of a single species. This situation implies a high degree of environmental adaptation and incidentally casts further doubt on the wisdom of irresponsible transplanting of local breeding stocks.

DISCUSSION

That a general relationship exists between intestinal length and amount of low quality, bulk food in the diet is well known among other groups of animals. Carnivorous fishes whose diets are high in protein, have short intestines as compared to those that feed on plant materials. Likewise predatory mammals have short and simple alimentary tracts, whereas grazing ungulates have long intestines and often complex stomachs. In the case of ungulates, an intestinal flora of bacteria and protozoa plays a part in food digestion, and storage room in the intestinal tract is needed to hold bulky food materials long enough for microbial decomposition of cellulose to take place, which process yields digestible carbohydrates used by the host animal. Apparently the same is true in gallinaceous birds. Suomalainen and Arhimo (1945) cultured bacteria from the caeca and intestines of three species of Finnish grouse (capercaillie, hazel grouse, and willow grouse) and demonstrated in the laboratory that the cultures actually did decompose cellulose. Hence the long caeca and intestines of all browsing galliforms probably may be construed as storage chambers for microbial decomposition of low-grade foods. Whether the added absorptive surface is likewise an essential feature of this arrangement is unknown. I am inclined to the belief that it also may be very important, for browse foods like pine or fir needles often are very low in protein, phosphorus and vitamin A, as well as being low in digestible carbohydrates, and it would appear that a grouse must extract every possible molecule of these essential ingredients to survive. Conversely, species and even subspecies living largely on concentrates like seeds, nuts, fruits, tubers and insects, can afford less efficient digestive systems. Doubtless these species also have intestinal floras but I presume they play a much smaller part in processes of digestion than in the browsing grouse.

Young of all galliforms, including the grouse, live during the period of rapid

growth on high protein diets dominated by insects. It is of interest to note that Suomalainen and Arhimo found microbial cultures from young grouse much less effective in cellulose decomposition than cultures derived from older birds. They did not determine why the microbes should be less active.

The fact that differences exist in gross intestinal morphology of the galliforms is but a clue as to actual differences in digestive processes. Critical investigation of the histology and enzyme secretions of intestinal structures and of the actual role of bacteria and protozoa in digestion doubtless will further clarify the problem of differential digestive abilities.

SUMMARY

Browsing galliforms of the grouse family were found to have materially longer caeca and somewhat longer intestines than seed-eating quails, partridges, pheasants and turkeys. Presumably these morphologic modifications permit the grouse to winter on sources of low quality bulk food, partly by providing storage room for microbial decomposition of cellulose and perhaps in part by permitting more complete absorption of all essential elements in the diet.

A parallel though less marked difference in intestinal morphology was found between two subspecies of California quail, one population, depending upon a relatively poor winter diet of bulk foods, having longer caeca and intestines than a nearby population with a richer average diet.

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Accepted for publication June 19, 1952.

FOOD HABITS OF MOUNTAIN QUAIL (*Oreortyx picta*) IN EASTERN WASHINGTON

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Little is known about the status, either at present or in the past, of mountain quail (*Oreortyx picta*) in eastern Washington. Some ornithologists believe that mountain quail were indigenous in the Blue Mountains of southeastern Washington; others state that this species was introduced. Actually both situations may have been true. Taylor (1923) stated that mountain quail were repeatedly introduced in various parts of Washington and these birds were reported from Yakima, Klickitat, and Asotin counties east of the Cascades at the time of his writing.

Records of the authors indicate that mountain quail are to be found in the Blue Mountain region as follows: Asotin Creek drainage, Asotin County; Rattlesnake Canyon which is located on the north side of the Grande Ronde River, Asotin County; and the Tucannon

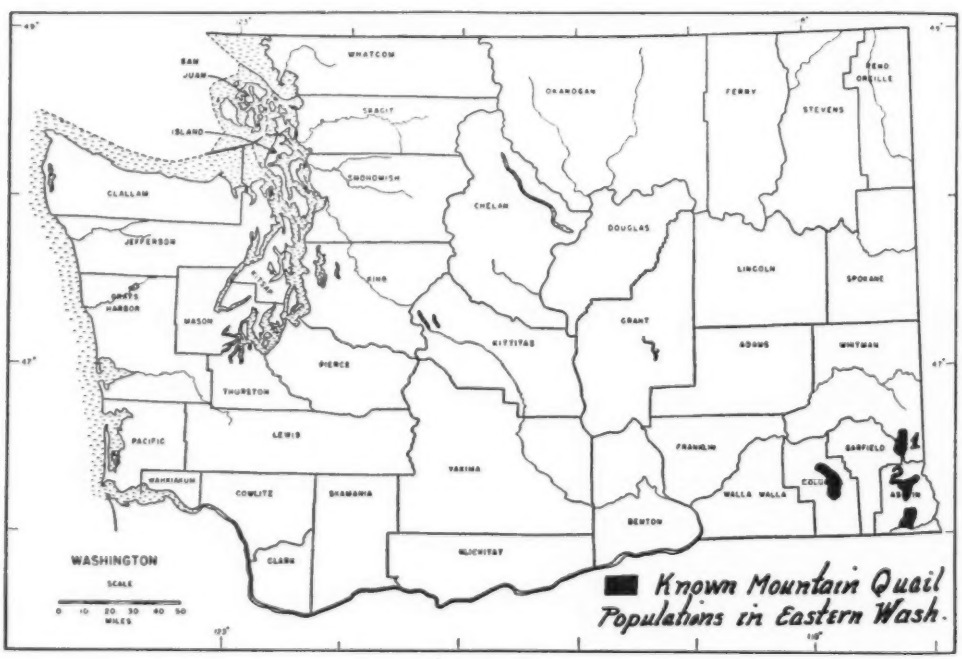

FIG. 1. Food habit samples were taken from populations 1 and 2.

River drainage, Columbia County. Also there is a small population in Steptoe Canyon, Whitman County (Fig. 1). According to Carl Reisenauer, these birds were planted on the Stewart Ranch at the head of Steptoe Canyon by the Lewiston Sportsmen's Club in 1926. This canyon runs into the Snake River in the vicinity south of Indian; the headwaters of this drainage border typical Palouse country (Yocom, 1943).

Within recent years mountain quail populations have fluctuated considerably in eastern Washington. In 1941 and 1948, populations were notably high and supported considerable hunting in Asotin Creek, Asotin County, and along the Snake River, Whitman County. Severe winters apparently decreased populations considerably. For example, there was a large population of mountain quail along the Snake River between Wawawai, Whitman County, and Clarkston, Asotin County in the fall of 1948. An unusually severe winter followed and no quail were seen in that area the next fall. A few mountain quail were reported there during the winter of 1951–1952.

FOOD HABITS

Investigations on food habits of this species have not been made in eastern Washington prior to this study. Data presented in this paper were obtained from birds shot during hunting seasons and a few additional birds collected later in the year. The samples represent birds shot from October 30 to December 16. Samples have been obtained from two populations; 18 from the Asotin Creek area and 15 from the population on the Snake River in Whitman County. Samples from the two populations have been treated as one in Table 1, for the areas represented are somewhat similar ecologically. In both cases the quail are found in stream drainages flowing through canyons cut through layers of dark basalt which forms the underlying rock of the Columbia Plateau (Bretz, 1928). South and west slopes are relatively arid, and thus have grass-forb associations. Clumps of rabbit brush (*Chrysothamnus* spp.) and sage (*Artemisia* spp.) occur on the drier slopes above the stream beds. North slopes are more mesic and often support *Amelanchier florida, Holodiscus discolor, Philadelphus lewisii, Physocarpus malvaceus, Rhus glabra,* and other less dominant shrubby species such as *Rosa* spp.,

TABLE 1.—CROP AND GIZZARD ANALYSIS OF 33 MOUNTAIN QUAIL

Species	27 Gizzards	26 Crops	
	No. of Occ.	No. of Occ.	Per cent of total Vol.
Grit	27	9	1.6
Chaff	21	11	2.8
Coccinellidae	..	6	1.8
Unidentified insect	4	..	...
Agropyron spicatum	..	2	3.0
Bromus sp.	4	..	...
Bromus tectorum	4	4	.7
Triticum aestivum	..	3	2.9
Alnus sp.	..	4	.9
Celtis douglasii	5	3	5.5
Polygonum aviculare	8	4	.9
Rumex sp.	6	6	Trace
Amaranthus retroflexus	..	5	1.2
Stellaria media	6	6	7.2
Crataegus sp.	9	..	...
Melilotus alba	4	..	...
Medicago lupulina	..	3	2.8
Robina pseudo-acacia	..	3	3.7
Trifolium agrarium	9	10	8.1
Vicia villosa	..	2	5.8
Erodium cicutarium	7	4	.7
Rhus glabra	18	11	22.7
Rhus toxicodendron	5	..	...
Solanum nigrum	..	4	2.5
Sambucus glauca	13	..	...
Symphoricarpos sp.	13	..	...
Helianthus annuus	6	6	2.9
Lactuca scariola	..	4	Trace

Ribes aureum, and *Symphoricarpos rivualris*. Along the streams are thickets of *Alnus tenuifolia*, *Salix* sp., *Populus trichocarpa*, *Celtis douglasii*, *Crataegus douglasii*, *Sambucus glauca*, and *Prunus* spp. (Fig. 2).

In the analysis of 27 gizzard and 26 crop samples which represent 33 quail,

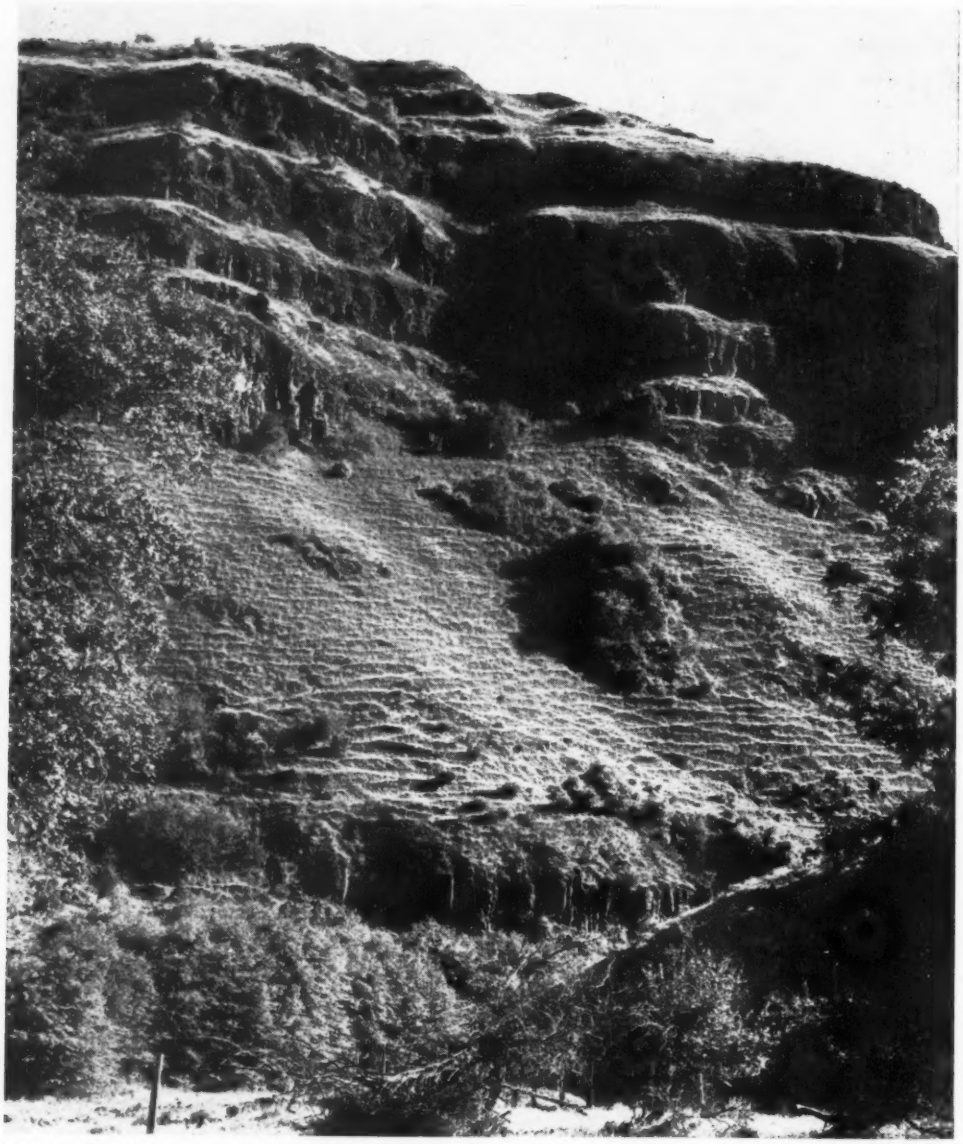

FIG. 2. Typical mountain quail habitat along Steptoe Canyon, Whitman County, Washington. Note the layers of basalt and thickets of deciduous shrubs on the north cliff facing. Thickets of alder occur along the stream.

95 different items were tabulated, of which 85 were plant species. This indicates the wide variation of foods consumed by mountain quail. Although a large number of items was consumed, relatively few were important from a standpoint of volume (Table 1). Smooth sumac (*Rhus glabra*) was the most important food from both volumetric and numerical occurrence standpoints. This species is very common, with fruits available at all times and especially in fall and winter when fruits are retained above snow level. Fruits from the previous year's production remain abundant on plants as late as June. Other plants which were relatively important foods were *Trifolium agrarium, Stellaria media, Vicia villosa, Celtis douglasii, Sambucus glauca, Symphoricarpos* sp., and *Helianthus annuus*. All of these are abundant and their seeds are available at the time that the birds were collected.

Animal life at this season was relatively unimportant as a source of food.

Other items found in traces or small quantities in fewer than four of the gizzards or crops are listed as follows (items that contain more than 2% of the total volume are included in Table 1 although they may have occurred in less than four samples):

Animal Matter—Locustidae, Coleoptera, Pentatomidae, *Formica* sp.;

Plant Material — Marsilia vestita, Pinus ponderosa, Agrostis sp., *Avena sativa, Echinochloa crusgalli, Elymus glaucus, Eragrostis* sp., *Glyceria borealis, Hordeum* sp., *Panicum* sp., *Phleum pratense, Sorghum vulgare, Chenopodium album, Corispermum hyssopifolium, Polygonum convolvulus, Polygonum persicaria, Amaranthus blitoides, Amaranthus graecizans, Amaranthus* sp., *Sisymbrium altissimum, Thlaspi arvense, Lithophragma bulbifera, Prunus virginiana, Prunus* sp., *Rosa* sp., *Rubus* sp., *Lotus americanus, Lupinus* sp., *Thermopsis montana, Trifolium repens, Trifolium incarnatum, Ceanothus* sp., *Malva rotundifolia, Caucalis microcarpa, Gilia aggregata, Amsinkia lycopsoides, Amsinkia intermedia, Amsinkia retrorsa, Verbena bracteata, Verbena hastata, Nepeta cataria, Datura stramonium, Plantago major, Sambucus melanocarpa, Dipsacus sylvestris, Arctium minus, Cirsium arvense, Cirsium lanceolatum, Senecio* sp., *Taraxacum* sp.

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Accepted for publication June 16, 1952.

OBITUARY

CECIL FRANZEN DeLaBARRE

1900 - 1952

Dr. Cecil Franzen DeLaBarre was born in Amherst, Nebraska, on July 5, 1900, and died, after a prolonged illness, at McGuire General Hospital, Richmond, Virginia, on September 10, 1952. He is survived by his wife, Elva Headley DeLaBarre.

Dr. DeLaBarre received his bachelor of science degree from Virginia Polytechnic Institute in 1926, and engaged in private business for several years, returning to V. P. I. and receiving his master's degree in 1930. His undergraduate training was in engineering and he came back to V. P. I. to continue his studies as a research fellow in experimental engineering. Later, due to his outstanding native ability in writing, he served as an instructor in English. The consuming interest which he always possessed in the out-of-doors drew him to the field of biology and eventually led to his appointment as full professor of biology in 1946. He obtained his doctorate degree in science education (Ed.D.) from Columbia University in 1948.

Perhaps Dr. DeLaBarre's most outstanding characteristic was his insatiable interest in varied fields. As an undergraduate he played varsity football, wrestled, and was on the track team. His vigorous physique and mind maintained his interest in athletics throughout his life despite his later activities in a wide assortment of endeavors. The vigorousness of his approach to all matters, academic or otherwise, was one of his attributes which made him a favorite teacher to scores of students. The interest and sympathy with which the students followed his prolonged illness was a graphic expression of their affection for him. When he spoke to his classes on hunting, fishing, conservation education, public relations, sportsmen's organizations, fly casting, firearms, report writing, and other similar matters so necessary to students of wildlife management, he spoke from a vast store of personal experience. His non-academic approach often produced outstanding results. The efficiency of modern firearms will long be remembered by the class to which he demonstrated how an old flint lock rifle could often be snapped several times before igniting the powder. His philosophy that no wildlife technician was worth his salt if he could not, from personal experience, talk the language and equipment of the sportsman who hired him was evident to all who studied under him.

He was a member of the American Association for the Advancement of Science, National Association for Research Science Teaching, Southern Association of Science and Industry, Virginia Academy of Science, Phi Delta Kappa, Kappa Delta Pi, American Legion, and Masons. He served as Assistant Unit Leader of the Virginia Cooperative Wildlife Research Unit from 1935 to 1952, was past president and long-time secretary of the Virginia Division of Izaak Walton League Chapters, and director of education for the Virginia Commission of Game and Inland Fisheries in 1940–41. Dr. DeLaBarre served in the Navy during World Wars I and II, and was discharged in 1946 with the rank of Commander. He took a very active part in the Naval Reserve.

Dr. DeLaBarre wrote easily and fluently. For several years prior to his death he wrote an outdoor column for the *Montgomery News Messenger*. This column, more than his serious papers, showed his real interest in everything out-of-doors and indicated his grasp of the over-all conservation picture. He was an avid hunter who was not ashamed of his interest in "dickey birds." He fished whenever possible, yet kept water snakes as pets. He kept dogs, but was a staunch advocate of the destruction of self-hunting dogs. In short, he kept a well-rounded perspective of where we were going in the conservation field, and refused to take any matter so seriously that he could not see both sides of the problem. DeLaBarre's attitude, so well imparted to his students, was that our conservation problems can be settled intelligently by discussing both sides. He refused to run head-on and waste his energies in any problem, personal or professional, to which

there was no known solution. Perhaps his last newspaper column, written only a matter of hours before he died, is as good a key to his character as may be given. The following article appeared in the *News Messenger* on the day of his funeral:

"After deep consideration of the proposition of an outdoor writer's taking annual leave during the latter part of the summer, just when the fishing is best, this writer has come to the conclusion that it is a sound idea and hereby declares that he is on annual leave. More will be heard from us later, we hope."

Dr. DeLaBarre will be missed by his students and co-workers in conservation; it is not likely that anyone can fully take his place.—*Henry S. Mosby.*

REVIEWS

The Conservation Yearbook 1952. A Directory and Guide to Facts, Figures and People in American Conservation. Edited by Erle Kauffman. The Conservation Yearbook, publishers, 1740 K Street, N.W., Washington 6, D. C. 288 pp., paper bound. $5.00.

The title effectively describes this useful new book, which contains a tremendous store of statistical, organizational, and personnel data in the conservation field. Every working conservationist will find many occasions during the year to consult the book. It is to be hoped that the book's sales do justify the annual revisions which are now planned.

The contents of direct interest to wildlife conservationists include government conservation organizations, their subdivisions, and key officials (the Fish and Wildlife Service receives proportionately less space than other conservation bureaus); state conservation agencies and officials; private conservation organizations, both national and state; the national parks, forests, and wildlife refuges, with pertinent data about each; a complete list of soil conservation districts; many forestry statistics; hunting license sales since 1919, fishing license since 1933, duck stamp since 1935; and big game statistics and fur harvest estimates.

A worthwhile venture which will doubtless increase in coverage and usefulness each year. —Gustav A. Swanson.

Traité de Pisciculture. Marcel Huet. Editions La Vie Rustique, Brussells, Belgium. xiv + 369, illustrated. 1952. Boards, 225 Belgian franks, clothbound, 285 B.f.

The author of this manual of fish culture, who is presently director of the research station of the Administration of Waters and Forests of the Belgian Ministry of Agriculture, has been an active worker in the field of limnology and freshwater fisheries for more than two decades. A student of Légèr, he has brought to bear his extensive experience with fish cultural problems in Europe, the Belgian Congo and South Africa on the preparation of a comprehensive but not highly technical handbook for the use of the practicing fish culturist.

Major sections of the book deal with culture of brook, brown and rainbow trout, and carp. Considered at less length are such species as eel, northern pike, black basses, various coregonids, and the tropically important cichlid, *Tilapia.* There are also sections on nutrition and growth, pond design, productivity, stocking rates, fertilization and weed control in ponds. The treatment of carp culture is, of course, aimed at direct production of fish for the table, and the section on trout culture gives such use equal weight with production for stocking of open waters.

Liberal use of illustrations, both photographs and diagrams, characterizes all sections of the book but perhaps is most helpful, especially to the foreign reader, in the sections dealing with location, design, and construction of ponds and hatcheries. Americans who have not visited Europe may be impressed by the scope and magnitude of commercial carp rearing discussed and pictured by Huet.

The formulas provided for determining carrying capacities, stocking rates, food con-

version, and expected yields from fertilized or unfertilized ponds, are based in large part on publications of Schaeperclaus and of Légèr. No doubt the author's own experience has led to modification or further substantiation of these formulas, but experimental work leading to their derivation is not included in the book. It is rather surprising to find very little space devoted to the diagnosis and treatment of fish diseases.

References to United States or Canadian publications in the bibliography are very few. The treatment accorded his subject by M. Huet is, as might be expected, almost wholly from the European standpoint. For this reason American readers will find his treatise of interest primarily as a source of information on methods and practices based on a fish-cultural tradition of several centuries' standing.

The paper stock used is of good quality, and the typography is clear and pleasing. With few exceptions the photographs have been well reproduced. Especially striking is the author's photograph of the nest of *Tilapia macrochir* from the Belgian Congo.

Because of the language barrier and the geographic restriction of the work, the manual could hardly serve as a working guide for the American fish culturist. However, fishery biologists, educators and administrators will find the book a useful addition to their libraries.—JUSTIN W. LEONARD, *Michigan Department of Conservation, Lansing, Mich.*

The Whooping Crane. Robert Porter Allen. New York, National Audubon Society. xxvi+246. June, 1952. $3.00.

"The second rarest living species of North American bird is the Whooping Crane. . . . For many years there has been a great deal of talk . . . but very little was done about it." Finally, two important steps were taken. In 1937, when the total population was reduced to 30 or 31 individuals, a refuge on the wintering grounds of coastal Texas was established by the Fish and Wildlife Service. In 1945, a cooperative research project was begun by the National Audubon Society and the Service. The purposes of the investigation were to reveal the life history of the species and to build a sound plan for its management and protection.

The publication, "The Whooping Crane," is the result of some four years intensive work on the wintering grounds near the Gulf of Mexico, along the far-flung migration routes, and in the Arctic where nesting is presumed to take place. The research was pursued with energy and originality. The book is an outstanding addition to the literature on rare and vanishing species of wildlife.

As a basis for field studies and deductions regarding the causes of depletion, an exhaustive search was made for distribution and abundance records. The history of the species begins with fossil remains of the Pleistocene and recent periods. It then jumps nearly 200 centuries to the first definite description of the bird, by Mark Catesby in 1722. Important distribution reports during the next 226 years (to 1948) are summarized in a remarkable list of 467 separate observations, arranged chronologically by States and Provinces from Florida and Durango to Keewatin and Mackenzie. Information on abundance is analyzed with the conclusion that the original population (as of 1869) was approximately 1300 birds.

"The heaviest kill took place between 1880 and 1919, a peak having been reached in the 1890's. . . . Most of the birds were killed while on migration (66%), while approximately 28% were killed on the wintering grounds and 5% during the breeding season." The range of the Whooping Crane shrank to "pinpoints of occurrence connected by thin trails leading resolutely north and south," while the population declined to perhaps 5% of the original.

A large portion of the book (pp. 1–86) is devoted to this melancholy record of "civilized" man's ruthless warfare and of the Crane's stubborn resistance to annihilation. A majority of the pages (pp. 87–195) deal with the life history: migration in Spring and Fall, food on the winter range and during migration, life in winter—including segregation and defence of territories, ecological relationships, limiting factors, and possibilities for management of the environment and of an important food animal, the blue crab, and, finally, the breeding cycle from courtship dance to year-old young. This section of the book records a great number of significant and interesting observations which are interpreted with originality and intelligence.

The final chapter, entitled "Survival: Protection and Conservation" (pp. 203–220), discusses: the results of measures designed to aid the remaining Whoopers (chiefly through establishment and operation of the Aransas National Wildlife Refuge, and studies on the area), cooperation of oil and gas companies in safeguarding the birds on their wintering grounds, the possible detrimental effect of cattle grazing on the Refuge, and the painstaking efforts (unsuccessful thus far) to aid injured Cranes to nest and rear young in semi-confinement.

The author makes a number of suggestions for improving management and protection on the Aransas Refuge. In addition, he urges establishment of a refuge along no less than 50 miles of the Platte River in Nebraska, where many of the remaining Cranes pause in their migrations between their winter and summer ranges. He also urges continued search for the northern breeding grounds, and promotion of a public education program to reach "hunters, farm boys and others in strategic locations along the migration route of the Whooping Crane, from Texas to Canada." (Reviewer's Note: To publicize this rare species and the need for protection during its especially vulnerable period of travel, it would be helpful to have the Whooping Crane proclaimed a Nature Monument under the Convention on Nature Protection and Wild Life Preservation.)

Important gaps remain to be filled in the life history of this species; the vital period on the nesting grounds, for example, is totally unknown. This monograph, therefore, is "unfinished." However, it is the most complete discussion which is possible at the moment, written by the biologist who has unquestionably the most thorough knowledge of the Whooper as a living organism.

The book is well printed. It is illustrated with spirited sketches by the author of Cranes in various postures, and of food plants and animals by Kay G. Morton and Joel W. Hedgpeth, respectively. In addition to these numerous line-drawings and several maps, there are 18 plates. A bibliography of approximately 475 titles is provided, as well as a 7-page index.

"The Whooping Crane" is more than a recital of facts concerning a bird species. It is a lively account, full of feeling and appreciation for the Crane as a majestic, living creature, without which North America would be a poorer continent. The author puts this feeling into dramatic words: "A Whooping Crane flock in migration must be classed with the Grand Canyon and Yosemite among the great natural wonders of North America." One finds humor, as well as awe, in the comparison of the male flock-leader with other members of the family group on the winter territory. "The male . . . seems to take his responsibilities quite seriously. Even his step, and the way he holds his head, are exaggerated. He reminds you of a certain type of old-time actor who dotes on heavy roles and fancies himself a *tragedian*. He is very solemn."

The author's tribute, and perhaps his evaluation of the species' future, can be summed up as follows: "For the Whooping Crane there is no freedom but that of unbounded wilderness, no life except its own. Without meekness, without a sign of humility, it has refused to accept our idea of what the world should be like. If we succeed in preserving the wild remnant that still survives, it will be no credit to us; the glory will rest on this bird whose stubborn vigor has kept it alive in the face of increasing and seemingly hopeless odds."—VICTOR H. CAHALANE.

The Raccoon. By Leon F. Whitney and Acil B. Underwood. Practical Science Publishing Company, Orange, Connecticut. 177 pp. 1952. $3.75.

The senior author, a veterinarian, has studied the raccoon for 32 years and the junior author is a breeder of rare color phases. Both are raccoon hunters, and thus have an opportunity, through the aid of excellent hounds, to observe these mammals more frequently and in a manner denied most of us.

They have divided their book into eighteen chapters: Habitat, Physical Characteristics, Raccoon Varieties, The Raccoon's Coat and Colors, Modes of Inheritance, Mental Characteristics, Food and Feeding Habits, Reproduction and Home Life, Enemies and Disease, Parasites, Hibernation, Travels, Legal Protection, The Racoon as a Laboratory Animal, The Tame Raccoon, Commercial Uses, Raising Raccoons, Feeding in Captivity, an additional bibliography and an index. Each chapter is

followed by references to the literature cited.

The first chapter is poorly organized and inadequate. General abundance levels, protective adaptations and fur density are briefly considered. Habitat preferences are not discussed in detail. This is unfortunate as the authors with their years of hunting and study could have particularized habitat requirements of the raccoon so as to assist in the management of this fur-bearer.

In discussing the physical characteristics of this mammal, the authors devote considerable space to a discussion of gigantism. The treatment directs attention to the danger of using weight as the sole measure of size in species disposed to fattiness.

In general the illustrations are good but add little to the value of the book. There are several annoying omissions which the reviewer feels could have been avoided by a critical review prior to publication. Some of the statements regarding relationships of raccoon to possible enemies such as bobcats and lynx, and possible prey species, such as game birds, are certainly unproven, and probably unwarranted.

The book is a valuable contribution and will be of use to the student of mammalian life histories, game manager, fur breeder and possibly to the laboratory technician.—ARTHUR H. COOK, *N. Y. State Department of Conservation, Ithaca, N. Y.*

The Sage Grouse in Wyoming. Robert L. Patterson. Wyoming Game and Fish Commission, Cheyenne, Wyoming. Published by Sage Books, Inc., Denver, Colorado. xii+ 341 pp. 1952. $5.00.

As a summary of much of the present knowledge of sage grouse, *Centrocercus urophasianus*, and a record of Dr. Patterson's research from 1948 to 1951, this book is a worthwhile contribution to the wildlife literature. Of the three approximately equal parts, the second is devoted principally to natural history and stands out with far more depth than the first on the sage grouse in the West, or the last which relates sage grouse to man's activities. Statements on life history are more carefully founded in fact and interpreted to more-or-less qualified conclusions, whereas much of the remaining portions are characterized by loose organization of factual material with little or no interpretation and often with little relevance to the general subject matter. More careful synthesis of meaningful data and concepts, consolidation by elimination of redundancy, and considerable trimming of material with little significance would have shortened and enhanced the book.

There is an overemphasis on "regularity" in sage-grouse population fluctuations based apparently on scanty data which are not tabulated, and complete concurrence with Wallace Grange's viewpoints on "game cycles."

Concepts on predation are contradictory, as if the author were attempting to please state departments of game while at the same time demonstrating recent ideas now prevalent among wildlife biologists. In one paragraph it is stated that badgers and ground squirrels were major sources of nest destruction, but that censuses revealed only minor changes in spring breeding populations on any of the study tracts. Yet badger control to reduce nest loss is recommended in the next paragraph with the added comment that badgers check the increase of ground squirrels which also prey heavily on sage-grouse nests. Predation is later interpreted as a force that checks overabundance of animal populations (apparently any kind) but does not impede population increase. Nowhere is the concept of intercompensating factors considered. Bobcat, badger, and coyote are assumed to have the true depressant effects on sage-grouse populations, but predator-control programs are not considered as important to increase in game populations as changes in the pattern of livestock-use of the range.

Part I, which succeeds fairly well in presenting an over-all view of physical and biotic environment, diseases, parasites, insect- and rodent-control programs and other factors influencing population density, contains a choppy, loose collection of material, much of which is repeated elsewhere. Broad statements leave the reader grasping for objective details. Many assumptions are not grounded on sufficient fact anywhere in the book.

The vivid description of activity on strutting grounds, courtship, mating, social dominance (in part based on marked birds) is well presented and is one of the highlights of the book. Much interesting general information on population dynamics is available in this section. It

is suggested that sage grouse are less likely to build dummy nests or renest than ringneck pheasants. The data show, however, that 19 per cent of the nests on one area and 15 per cent of the nests on another were listed as deserted when found; 23 per cent were destroyed on the first area and 57 per cent (most of which were thought to have been deserted before they were found) were destroyed on the second area. As with pheasants the actual nesting success under natural, field conditions may be nearly identical with that under the most propitious penned conditions, indicating that predator control to reduce nest losses may not result in higher populations. One would like to know more about the reasons for the higher nesting success (54 per cent) on the Eden Valley Area than the Sandy-Pacific Creek Area (26 per cent). Nest density averaged 42 nests per square mile on the former and 58 per square mile on the latter. Nesting habitat was superior on the mountain foothills of the Sandy-Pacific Creek Area than on the Eden Valley Irrigation Area. Perhaps the lower density resulting from trapping on the Eden Valley Area increased the reproductive gain through higher nesting success. It is demonstrated that inclement weather immediately following hatching was responsible for lower numbers of young in 1949 compared with 1948; this is followed by the statement that decimating factors of predation, highway mortality, and illegal hunting are considered far more important to juvenile mortality than weather. Since both natality and juvenile mortality may exhibit wide annual variations, it seems difficult to formulate a precise statement as to which is the more important. The depressant effect of weather, decimating factors, and the relationships between these two groups of factors are likely to change from year to year.

Deficiencies of food, cover and water are considered nonexistent because the habitat is composed of "climax" plants and mature physiography. If most of the vegetation in Wyoming has not been disturbed by overgrazing, elimination of fires, agriculture, and other activities of man, it is indeed unique in North American vegetation. The discussions in Part III clearly indicate intense anthropic influences. Under the description of the plant environment it is stated that, "As a result of improper land practices, numerous areas in this region which originally supported pure grass types have reverted to the sagebrush climax." How does vegetation "revert" to sagebrush "climax?" One wonders what is meant by climax, what the existing vegetation really is, and what changes are taking place. It seems probable that more sagebrush exists today than prior to the white man's influence and that sage-grouse populations increased with the increase in disturbance vegetation of this type.

The increase in weight during winter is most interesting. Perhaps such gains reflect a greater consumption of sagebrush which is high in fat content, though the phenomenon also suggests remarkable efficiency in regulating body insulation at low temperatures. Percentage chemical composition of black sagebrush is compared with that of sage-grouse droppings to indicate the digestibility values. Such percentages would have more meaning if the items were expressed in grams per gram of lignin. The percentages, which add up to 109 per cent in each column, are difficult to interpret in terms of digestibilities.

The movements of released birds are remarkable. Bands were returned from 88 out of 500 sage grouse released. Fifty-five per cent of 152 adult males and 80 per cent of 52 adult females traveled 20–40 miles to return to the vicinity of capture within 7 weeks. Of 209 birds released down-drainage from the trapping locality, 16 bands were recovered at the site of capture. None of the 739 birds released at higher elevations returned during the year of release, indicating that adult birds tend to migrate to upper drainages during summer and early fall. Several returned the following year. One adult male and one adult female returned a distance of 100 miles the year following release. A juvenile male traveled 75 miles over two high mountain ranges, probably following drainage patterns. Immature birds were more inclined to remain in the vicinity of release than adult birds.

Shifting harvests to autumn instead of confining them to the current August season is recommended. Hunters prefer young birds and frequently discard old birds in August when juveniles are recognizable. Early seasons place considerable shooting pressure on females and

young while they are still concentrated on breeding and rearing ranges; populations would be more widely scattered and more males would be harvested in later seasons.

Much of Part III that deals with agricultural economics, industrial and agricultural development of the West, and policies of Federal agencies might well have been omitted or discussed by some authority in these fields. The Office of River Basin Studies of the U. S. Fish and Wildlife Service is severely and not altogether justifiably criticized for not giving proper attention to the interests of sportsmen, viewpoints of state departments of game, and the welfare of wildlife—the very purposes for which the Office was established. Such criticism appears to stem at least in part from Dr. Patterson's deep reluctance to witness the decline of sage-grouse populations with the advance of more extensive irrigation, sagebrush irradication, and other aspects of intensified agriculture and range management, a point of view shared by many who enjoy the esthetic and recreational aspects of wildlife. There can be no doubt that many irrigation, navigation, flood control, and power projects in various parts of the country are not in the best interests of proper land use and that they stem from the selfish interests of local groups. The Office of River Basin Studies has been a valuable agency in gathering information to stem the tide of ill-founded projects and has done little to perpetuate them.

The book ends with an optimistic note that sage-grouse populations have been restored to high levels of abundance in many areas of the West and that these populations will remain as long as the sagebrush vegetation is maintained. It is believed that sagebrush will continue to dominate grazing lands, despite the implications one might foresee in the use of chemical plant eliminators and other methods of removing shrub vegetation to establish grasslands with higher productivities for livestock.

One of the most useful contributions of this work is that it suggests many fertile fields for future research on sage-grouse populations. The superb photographs, incidentally, add much to the book.—HELMUT K. BUECHNER, *Department of Zoology, State College of Washington, Pullman, Washington.*

Proceedings of the United Nations Scientific Conference on the Conservation and Utilization of Resources (17 August–2 September 1949, Lake Success, New York). Vol. VII, Wildlife and Fish Resources, 259 pp., printed in English. $2.50. U. N. Publ. Sales No. 1950.11.B.8. Dept. of Economics Affairs, United Nations, N. Y., 1951.

This is the seventh of the volumes that have resulted from a conference of scientists and administrators from more than 50 countries. One hundred contributors of papers and discussants considered the following subjects: (1) Changes in Abundance of Fish Populations, (2) Developing Fishery Resources, (3) Fisheries Statistics and Technological Development, (4) Management and Cultivation of Fresh-water Fish, (5) Research in the Conservation and Utilization of Marine Resources, (6) Game and Fur Conservation, and (7) Management of Wildlife Resources. The 68 published papers constitute an important contribution to the literature of conservation. Approximately 70% (48 papers) deal with fisheries and marine resources.

The papers on Changes in the Abundance of Fish Populations contain much of interest and value to fisheries administrators and biologists. When considered with the papers which appeared in "A Symposium on Fish Populations" (Bingham Oceanographic Collection, Vol. XI, 1948), they should serve as an excellent guide to the study of modern fishery biology theory and problems. Included were analyses of long term studies on cod and herring in northern European waters and of herring off British Columbia where fluctuations in abundance are pronounced. These fisheries are characterized by dominant year class phenomena which seem to be determined in an early planktonic stage of the fish life history. Overfishing apparently is not an important factor. It was emphasized that long-term hydrographic studies of the sea are needed to determine the factors which make for a dominant year class. A. V. Tåning pointed out that climatic changes in our time (affecting northern Atlantic waters) have caused long periodic fluctuations in some stocks such as that of cod. Other papers considered "overfishing theory" as it applied to particular cases such as anadromous salmonid fishes in Norway

where it was said that there has been evidence of overfishing for hundreds of years, and where much greater yields have been obtained following the abandonment of certain types of fishery which apparently had permitted too little yearly spawning escapement. Michael Graham gave examples mainly from the northern European trawl fisheries (plaice, sole, turbot, cod and haddock) showing that overfishing may and has occurred and gave the signs that indicate when there may be too much fishing for the stocks. Changes in the North Sea stocks of fish were outlined (p. 166). He also advises that the best management is to leave a fishery alone until evidence shows that overfishing is approaching, and that it was for those who maintained that there was overfishing to furnish proof of it. H. A. Dunlop reviewed the history and results of regulation of the Pacific halibut fishery where the thesis is held that the amount of fishery determines the sizes of the stock of halibut and the annual yield it can produce, a view recently challenged by Burkenroad (Bull. Bing. Oceano. Coll. 11(4): 81).

Means for the development of latent fishery resources, shellfish management, the propagation and transportation of marine fish in Europe, and the utilization of marine algae were reported. An estimate was given of the fisheries production in various sections of the highly productive northern hemisphere and the main latent resources especially in the southern hemisphere were appraised. A map shows the location of latent marine fishery resources with major stocks believed to be underfished in 1949.

Five papers treated generally of fisheries statistics, six gave recent advances in technological methods of handling and processing fishes and three dealt with improvements in fishing methods.

The section on Management and Cultivation of Warm-water Fish includes 12 papers that reported largely on pond culture practices in many parts of the world. Of especial importance are the bibliographies of the published papers. The results of experience and problems in pond culture in Japan, China and southeast Asia, Philippines, Indonesia (where fish is the principle source of edible animal protein), India, and Israel are summarized. Studies are under way on the use of organic and inorganic manures, competition (several species often gave better total yields apparently by better utilizing all niches), control of malarial mosquitoes in rice paddies, attempts to increase natural foods, studies of density levels, and production. A table gave yields and food requirements of ponds in many countries. While several Cyprinidae, especially the carp (*Cyprinus carpio*), were usually the species involved, data on other species, especially the milkfish and mullet were included.

Under the heading Game and Fur Conservation the problems of game conservation on croplands in Great Britain were discussed and for the United States, four papers treated of wildlife on cropland; recreation, game and fur conservation on western rangeland; and ecological aspects of deer production on forest land.

Fifteen papers were included under Management of Wildlife Resources. Five papers considered the relation of game to the control of disease in domestic cattle, the controlled area system, and the role of national parks in Africa (Kenya, Northern Rhodesia, Belgian Congo and central Africa). The administration of big game resources in the United States and the status of wildlife in France were treated. The problems of the conservation and protection of bird resources were reported on a world-wide basis. Two papers discussed game bird conservation in Canada and the United States with emphasis on survey and control methods. The problems peculiar to the Peru guano islands and to New Zealand were also treated. —EDWARD C. RANEY.

RECENT PUBLICATIONS

A Wildlife Management Plan for Allegany County. By Robert A. Reed. Allegany County Federation of Sportsmen's Clubs, Belmont, N. Y. 40 pp. Undated (1952).

This unusual publication, prepared by Robert Reed (who is District Conservationist with the Soil Conservation Service, as well as being President of the Allegany County Federation of Sportsmen's Clubs), gives basic information on the land use, the conservation practices, and the wildlife conservation needs in Allegany County. This county already has an outstanding record in the state for conservation projects conducted by sportsmen's clubs, and this publication is designed to encourage still more work of that kind. Individual copies are reportedly available from Mr. Reed.

Whirring Wings. The Bobwhite Quail in Missouri. By Jack A. Stanford. Missouri Conservation Commission, Jefferson City, Missouri. 96 pp. illus. 1952.

A beautifully prepared and illustrated popular bulletin which will be of great interest to wildlife technicians, as well as to the sportsmen for which it was primarily produced. The second part of the bulletin, beginning on page 59, takes up techniques of management.

Pheasant Food Habits in South Dakota. By Carl G. Trautman. South Dakota Department of Game, Fish and Parks, Pierre, South Dakota. Technical Bulletin No. 1. Federal Aid in Wildlife Restoration Project 17-R. 89 pp. 1952.

A study based on 1679 pheasants collected during the years 1946–48, together with supplemental studies on crop damage.

Muskrats on Tidal Marshes of Dorchester County. By Van T. Harris. Chesapeake Biological Laboratory Department of Research and Education, Solomons Island, Maryland. Publication No. 91. 36 pp. 1952.

Annual Report for the Year 1950 *and Short Papers.* Institute of Freshwater Research, Drottningholm, Sweden. Report No. 32, Fishery Research Board of Sweden. 152 pp. 1951.

Eleven research reports of general interest to fishery biologists and limnologists.

An Investigation of Some Problems of Ecology of the Beaver in Northern Manitoba. By John Blake Nash. Department of Mines and Natural Resources, Game and Fisheries Branch, Manitoba. 64 pp. April 1951. (Multilithed)

Sharptails Into the Shadows? By Frederick and Frances Hamerstrom and Oswald E. Mattson. Game Management Division, Wisconsin Conservation Department, Madison 2, Wisconsin. Wisconsin Wildlife No. 1. Pittman-Robertson Project 13-R. 35 pp. 1952.

A Review of the Living Representatives of the Genus Alces. By Randolph L. Peterson. Contributions of the Royal Ontario Museum of Zoology and Palaeontology, Toronto, Canada. No. 34. 30 pp. October 15, 1952.

A systematic study which follows other recent authors in placing the North American forms of moose into the species *Alces alces.*

Parental Care and Its Evolution in Birds. By S. Charles Kendeigh. University of Illinois Press, Urbana, Illinois. 356 pp. 1952. $4.00 paper, $5.00 cloth.

Students of bird behavior and life histories will find in this book an exceedingly valuable compendium of information on the behavior of birds during nest-building, incubation, and the period of caring for the young. The literature has been covered through 1950, and the 40-page "literature cited" section will be of particular value to students. Readers of the Journal will be especially interested perhaps in the sections on game birds, which are brief, but do cover the most important literature in the field.

The house wren, which the author has studied so intensively for many years, is given the most attention, with an admirable summary of the author's comprehensive work on this species. Dr. Kendeigh has rendered biologists generally a real service by this valuable contribution.

Waterfowl Banding 1939–1950. By Ducks Unlimited. Published by Ducks Unlimited, Winnipeg, Manitoba, Canada. October, 1952. 53 pp.

BRIEFER ARTICLES

BRUCELLOSIS IN A MOOSE, *ALCES AMERICANUS*[1]

William L. Jellison
Rocky Mountain Laboratory, Hamilton, Montana
Charles W. Fishel
Montana State University, Missoula
E. L. Cheatum
Montana Cooperative Wildlife Research Unit, Missoula

On May 26, 1951, an autopsy was performed on a young moose that died at the Red Rocks Lakes Wildlife Refuge in the Centennial Valley, Beaverhead County, Montana. The animal had been under observation for several days and was obviously ill. It had been dead only a few hours when autopsied.

The animal was a young female estimated to be 3 years old and weighed 430 pounds. It was thin but not in a starvation condition. External examination revealed no injury or conspicuous cause of death. A few winter ticks, *Dermacentor albipictus* Packard, were found on the hide. The carcass was completely skinned but no external wound, bruise, or other evidence of mechanical injury was noted. There was a rather deep wound in the anterior palate.

The only significant pathological findings were as follows: the pericardial sac was distended with fluid; there was a fibrinous film over the upper half of the heart and the heart showed a marked pericarditis and myocarditis.

Plate cultures of pleural fluid and pericardial fluid both yielded growth suggestive of *Brucella* in 48 hours. Primary isolation transfers were typical of *Br. abortus* by cultural characteristics and antigens prepared from them were agglutinated by known positive *Brucella* serums, thus confirming the identity.

Pericardial fluid was injected into a series of guinea pigs. After 42 days sera from these test animals gave positive agglutination tests with *Brucella* antigen and cultures of *Br. abortus* were isolated from their tissues.

The serum of this moose was tested several times for agglutination of *Br. abortus* antigen by the test tube technique using Bureau of Animal Industry antigen. Complete agglutination was observed in one test at a serum dilution of 1:20,000. One of the cultures isolated from the moose was agglutinated by the animal's serum diluted 1:6000.

Blood smears showed about one percent jolly bodies in the erythrocytes. Preserved portions of the heart and lymph nodes were sent to Dr. Charles L. Davis of the Bureau of Animal Industry Pathology Laboratory at Denver, Colorado, who summarized his findings as follows: "The histopathological diagnosis in this case is subacute pericarditis and myocarditis, with associated arteritis of the myocardium and lymph nodes. The immediate cause of death is problematic and may be difficult to determine. I would look upon the arterial changes, particularly in the heart, as the probable cause of death, and the animal may have actually died of acute myocardial failure. However, others may consider death due to bacteremia."

During the fall hunting season of 1951, 44 blood samples from moose were sent in by hunters in Montana. These were tested for agglutination of *Br. abortus* using the test tube technique. Thirty-five were entirely negative, 3 gave complete agglutination at a titer of 1:20 only and 6 gave complete agglutination at 1:40. The only two samples received from Centennial Valley had titers of 1:40. These reactions are of doubtful significance and would only be considered suspicious if encountered in a dairy herd.

Brucellosis infection in a moose has been reported in at least one other instance by R. Fenstermacher and O. W. Olsen (Further studies of diseases affecting moose. III. Cornell Vet. **32**(3): 241–254, 1942) in Minnesota. In their experience an exceedingly high blood

[1] From the Federal Security Agency, Public Health Service, National Institute of Health, National Microbiological Institute.

serum titer, i.e., 1:50,000, was found for *Brucella abortus*. *Br. abortus* was isolated by direct culture from blood, liver, lungs, kidneys, spleen, and lymph nodes. *Br. abortus* was also cultured from the spleens of guinea pigs that had been injected with various tissues. This animal had been under observation for 6 days and though he became weaker the last 3 days he was sacrificed in a very weakened condition before death ensued. They made no positive statement as to whether or not they considered *Brucella* infection the principal cause of illness. Numerous other moose examined by them were all negative for *Brucella* by agglutination tests.

We have no conclusive proof that *Brucella* infection was the cause of death in this animal but consider it highly probable in the absence of any other obvious cause.

Accepted for publication June 25, 1952.

IMPRESSIONS OF FISH SCALES IN PLASTIC

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Scale impressions on plastic sheeting have been prepared at the University of Missouri Wildlife Research Unit since 1951 with a Carver Laboratory Press.[2] This new model ten-ton hydraulic press (Fig. 1) is equipped with a pressure gauge calibrated in pounds. Heat is supplied by a Carver electric hot plate attachment with accurate thermostatic control of both plates to temperatures of 400° F. This arrangement provides constant heat and pressure for a large series of successive impressions. Different temperatures and pressures are available for different plastics.

Clear, complete impressions have been secured with a pressure of 10,000 pounds and a temperature of 110° F. using cellulose-acetate Lumarith.[3] The plastic is placed in the press to warm for one minute, pressed for one minute, then removed and placed under a weight to prevent curling while cooling.

Several different methods of preparation of scales for pressing are in use at this Unit. These methods have been developed independently by Edward M. Lowry and Mercer M. Patriarche of the Missouri Conservation Commission, Fisheries Section, and by the junior author. In each instance a 3″ x 5″ sheet of gummed paper, of thin cardboard, or of metal, supports the scales and over this is laid a 3″ x 5″ sheet of plastic. This arrange-

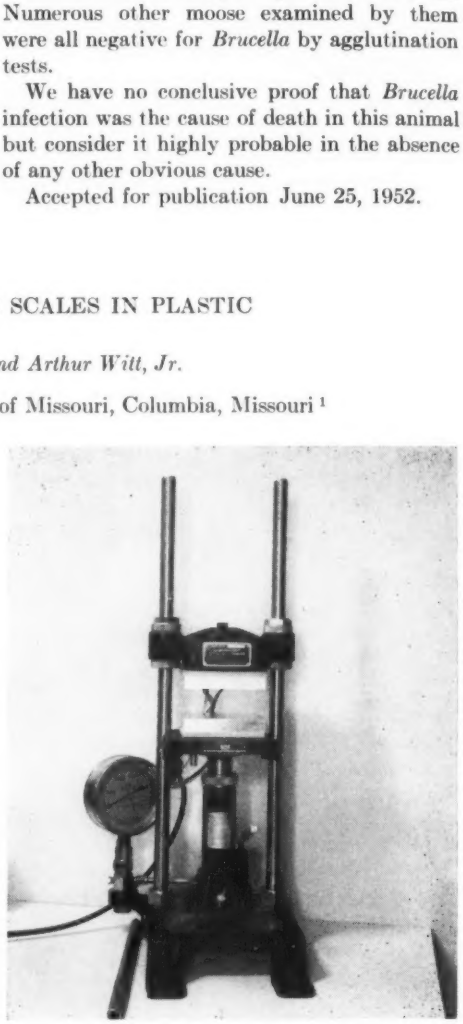

FIG. 1. Hydraulic press with hot plate attachment used by the University of Missouri Wildlife Research Unit for preparation of plastic impressions of fish scales.

[1] Contribution from the Missouri Cooperative Wildlife Research Unit: U. S. Fish and Wildlife Service, Wildlife Management Institute, Missouri Conservation Commission, Edward K. Love Foundation, and University of Missouri cooperating.

[2] Purchased by the Research Council of the University of Missouri from Fred S. Carver, Inc., New York, N. Y.

[3] For specifications see Edward M. Lowry, 1951. A nomograph for rapid back-calculation of fish lengths. Prog. Fish Cult., Oct: 199–204.

ment permits simultaneous impression of one to four scales from each of fifteen different fish. It is unnecessary to clean the scales provided excess mucous is scraped away before scales are removed from the fish. The plastic impressions are conveniently stored in a standard filing drawer for 3″ x 5″ cards. A discussion of these impression methods follows:

(1)A strip of gummed paper, 3″ x 5″, is ruled into one-inch squares each identified by the collection number of a separate scale sample. Each square contains one or more scales from one fish. The scales must first be soaked until they are pliable. Excess moisture is removed by blotting, and then the scale, while moist, is pressed onto the mucilage. Excessive moisture on the scale will allow some of the adhesive to flow onto the surface of the scale, impairing the impression. This is the most tedious of the methods described. The gummed paper with attached scales may be retained permanently, however, and an unlimited number of impressions for purposes of demonstration or exchange may be prepared. This is a modification of the technique used by Louella Cable (correspondence) of the Fish and Wildlife Service.

(2) Three strips of cellotape three-quarters of an inch wide are laid with the gummed surface up over a 3″ x 5″ card ruled in one-inch numbered squares. Scales are stuck to the gummed cellotape over appropriate squares. The plastic sheet is then pressed onto the cellotape, and the whole placed in the press. After cooling, the cellotape peels away from the plastic pulling the scales with it. This method is especially useful for the handling of very small scales, since they will not become lost once they touch the cellotape. Another advantage of the method is that dry scales, scales removed directly from fish preserved in alcohol or in formalin, or scales soaked in water will adhere to the tape.

(3) A 3″ x 5″ card is ruled into one-inch numbered squares. In each square is laid one or more dry scales from one fish. The scales are arranged but are not fastened in position. Over this the plastic sheet is laid and the whole pressed directly. The card leaves a rough, frosted background about the scale impressions which some consider a disadvantage during scale reading.

(4) A metal ferrotype platen 3″ x 7″ is scribed near one end into fifteen one-inch squares. At the opposite end a one-inch strip is bent up at an angle of 45° to facilitate handling. The scales are arranged on the polished surface as in method (3). The plastic is laid over the scales and a second metal ferrotype platen, 3″ x 5″, is placed on top with the polished side down. The bent strip on the lower platen facilitates moving the scales to and from the heated press. An advantage of this method is that the background about the scale impressions is smooth and transparent which facilitates the reading of small scales. To aid in the handling of small scales a mixture of albumen and glycerine is spread over the platen to provide an adhesive surface. This impression method and the preceding are the least laborious.

Accepted for publication June 19, 1952.

FOOD CONVERSION IN BLACK BASSES OF THE GENUS *MICROPTERUS*[1]

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Experiments in the use of shortened food chains to produce maximal yields of black basses inevitably lead to considerations of the efficiency of food conversion (e.g., Swingle, 1949). It is also a matter of interest to compare smallmouth bass and largemouth bass in this regard. Reported here are the results of feeding known weights of forage fishes to 4 smallmouth bass, *Micropterus d. dolomieu* and to 3 largemouth bass, *Micropterus s. salmoides*.

The experimental work was conducted at Camp Filibert Roth, field station of the University of Michigan's School of Natural Re-

[1] Contribution from the Department of Fisheries and Camp Filibert Roth, School of Natural Resources, University of Michigan.

sources, on Golden Lake, Iron County, Michigan. Both the basses and the fishes fed to them were taken from lakes and streams of the vicinity. Individual bass were kept in six glass-sided aquaria. These tanks were filled to their 15-gallon capacity and covered with 1/4-inch square mesh, galvanized iron screen. In order to simulate natural conditions of light and temperature these tanks were kept out-of-doors and were supplied with running water pumped from Golden Lake. One additional smallmouth bass (No. 6) was kept for comparison in a 3-foot by 4-foot galvanized tank in the lake. The bottom of this enclosure was made of window screen (about 1/16-inch square mesh) and was covered by about one foot of water. The tank rested on a pedestal about 3 feet above the bottom of the lake. Another similar container in the lake served as a holding pen for fishes to be fed to the bass. The fish in all tanks presumably had equal access to such plankton as was in the common source of water. We have no measure of the amount utilized, if any.

We arbitrarily set three forage fish as the average 2-day diet to be given to each bass. The forage fish eaten by the bass were 272 *Eucalia inconstans*, 36 *Semotolis a. atromaculatus*, 21 *Margariscus margarita*, 13 *Boleosoma n. nigrum*, 10 *Cottus* spp., 9 *Chrosomus eos*, 8 *Pfrille neogaea*, 7 *Umbra limi*, 3 *Notropis h. heterolepis*, 1 *Poecilichthys exilis*. Just prior to feeding, the lot of fish to be offered in each experiment was wiped dry of moisture on absorbant paper toweling, weighed in water with only moderate accuracy to the nearest 0.1 gram, and presented alive to the recipient bass. Some selection of forage organisms was made according to size, the smaller individuals being given to the smaller bass in order to favor capture and deglutition. Fish that were refused by the bass were removed, weighed, and subtracted from the record of the initial offering. Sometimes this was done within an hour after feeding when handling had brought on death of a small forage fish (it soon became evident that the bass would spurn a dead fish). At other times, fish of one feeding which had not been consumed by the next feeding were removed and subtracted from the account. Often these fish had been killed as a result of pursuit and injury by the feeding bass. In other instances, apparently we had offered a prey item too large to be tempting or acceptable.

All bass showed substantial increases in weight and some increment in length (Table 1).

TABLE 1.—GROWTH DATA AND FOOD CONVERSION FACTORS FOR BLACK BASSES ON A FISH DIET

Data Item	Experimental Bass						
	Largemouth			Smallmouth			
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Initial weight, gms.	13.2	12.0	20.5	56.8	58.6	39.9	275.0
Terminal weight, gms.	16.0	19.7	32.5	83.4	90.3	58.5	323.0
Gain in weight, gms.	2.8	7.7	12.0	26.6	31.7	18.6	48.0
Entry date	July 8	July 8	July 8	July 8	July 8	July 9	July 9
Closing date	Aug. 6	Aug. 6	Aug. 6	Aug. 6	Aug. 6	Aug. 6	July 31
Days for weight increase	29	29	29	29	29	28	22
Gain in weight per day, gms.	0.1	0.3	0.4	0.9	1.1	0.7	2.2
Weight of food consumed, gms.	15.6	22.1	47.0	100.0	104.2	65.5	196.1
Percentage of starting body weight fed	118	184	229	176	178	164	71
Percentage increase in body weight	21	64	59	47	54	47	17
Food conversion factor	5.57	2.87	3.92	3.76	3.29	3.52	4.08
Date of first length measurement	July 16	July 16	July 16	July 16	July 16	July 9	July 9
Days for length increase	21	21	21	21	21	28	22
First total length, mm.	106	105	132	176	172	157	290
Gain in length, mm.	9	12	10	11	14	11	2
Gain in length per day, mm.	0.4	0.6	0.5	0.5	0.7	0.4	0.1

They were weighed at the start of the experiment, twice during its course, and at the conclusion in the manner used for the forage fish. Total length measurements were with a fishery measuring board read to the nearest millimeter (Table 1).

The average food conversion factor for both bass species approaches 4.0, with that for the largemouths 4.1 and that for the 3 smallmouths of comparable size, 3.5 (for individual quotients see Table 1). The conversion factors are the simple quotients of dividing weight of food consumed by amount of weight gained for each individual bass. Other workers have obtained values similar to ours, although their experimental procedures were somewhat different. Using large numbers of yearling largemouth bass held in outdoor concrete ponds in Alabama, Prather (1951) obtained an average factor of about 4 for 138 specimens, although individuals varied from 1.5 to 24.2. Earlier, Thompson (1941) had found an average factor of 2.5 (quotient presumably adjusted to apply to 10-inch bass) using individual largemouth bass in aquarium tests more nearly like ours. Thompson and Bennett (1939) reported that Langlois in Ohio was able to convert ground carp into bass in hatchery ponds at the ratio of 5 to 1.

Apparently retension of the experimental bass in outdoor aquaria did not affect feeding behavior and metabolism any more than holding in the lake tank (Table 1). Smallmouth No. 6 in the latter was nearly the same in size as Nos. 4 and 5 in the aquaria and showed a similar food conversion factor (3.5 for the lake fish, 3.8 and 3.3 respectively for the aquarium-held ones).

From the existing, sparse information on food conversion in bass we may judge that the foraging demands of the species are high. This is currently recognized in bass management in the efforts to employ species combinations for optimal quantitative and qualitative forage bases in the production of bass. However, there is indication in the work of Thompson (1941) on largemouth bass and of Breder (1928) on the bowfin (*Amia calva*) that greatest efficiency in food conversion may be attained at less than maximum levels of feeding (hence, perhaps, at sub-maximum levels of forage populations).

Gain in length of the six smaller basses which we used averaged about 0.5 mm./day for largemouth and 0.5 mm./day for smallmouth in our aquaria. This compares reasonably well with data on the same or related fishes by other workers. Growth is, however, somewhat less than that for species commonly considered to be more predacious than bass: averages for pike (*Esox lucius*) (in rearing ponds) range from about 0.1 to 2.6 mm./day for young-of-the-year (Carbine, 1945) and in nature as much as 3.3 mm./day (Carbine, 1942).

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Accepted for publication April 28, 1952.

WATERFOWL ACCIDENTALLY CAUGHT IN MUSKRAT TRAPS

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During a study of muskrats on the state-owned Locomotive Springs Refuge in western Box Elder County, Utah, opportunity was afforded to study the relative effects on ducks of muskrat trapping at different seasons. For many years, trapping of muskrats was done in both fall and spring. Recently the trapping season has been in the spring from February 15 to April 1. Many trappers claim fall and early winter trapping to be more advantageous to them than spring trapping.

Wildlife administrators have been concerned about the number of ducks which are caught and killed in muskrat traps. The importance of this type of mortality has not been previously recorded for Utah. Gashwiler (1949. The effects of spring muskrat trapping on waterfowl in Maine. Jour. Wildl. Mgt., **13**: 183–188.) calculated that 4165 ducks were caught in spring trapping during the 1946 Maine season. He concluded that waterfowl trapping was a serious concern to the black duck.

In mid-winter trapping in Utah, December 26, 1950 to February 11, 1951, done on an experimental basis by one trapper under special permit, 38 ducks and 1 coot were caught while trapping 166 muskrats. This represents one duck per 4.21 muskrats taken. Maine figures were one duck per 14.7 and 17.7 muskrats respectively for the 1946 and 1947 seasons (Gashwiler, *op. cit.*).

A census of waterfowl on the Refuge, January 10–11, 1951, gave a total of 1085 wintering ducks. On this basis, 3.5 percent of the total wintering population had been caught in muskrat traps. Muskrat trapping was concentrated in open water near springs and along streams leading from springs to shallow frozen lakes. Ducks also frequented the open water of the springs. Because trapping was done largely along streams, traps with drowning rigs were predominantly used. Use of these drowning sets resulted in 69.3 percent of the captured ducks being killed by drowning. Maine studies showed that 47 percent of ducks caught in muskrat traps were drowned.

The species composition of the trapped ducks followed the relative abundance of those species in the wintering population. The mallard was predominant in the wintering population, constituting 63.2 percent of the total ducks; the pintail was next, comprising 21.0 percent; followed next by the green-winged teal with 13.2 percent; and the shoveller with 2.6 percent.

In the regular trapping season, February 15 to April 1, 1951, two other trappers in the widespread marshes caught 788 muskrats and 8 ducks or about 98 muskrats to each duck caught. Only one duck was caught while taking 646 muskrats during the spring season by the same trapper who trapped during the winter.

Thus, in Utah, spring trapping of muskrats where the water is open and ducks are scattered, results in greatly reduced numbers of trapped ducks. In management of the muskrat and waterfowl resource, it would appear wise to prohibit trapping of muskrats until the shallow waters are free of ice.

Accepted for publication April, 1952.

PREGNANT YEARLING COW ELK

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and

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On January 7, 1952, during an authorized reduction of elk in Rocky Mountain National Park, a male fetus was collected from a long yearling cow. Her age was estimated at 20 months, and the lower jaw was collected for verification. Development of the teeth was as follows: *Incisors*—only 2 were permanent, the other 6 were deciduous (milk teeth). *Premolars*—all 3 were deciduous, and there was no indication of permanent teeth erupting beneath them. *Molars*—only 2 were in use, the 3rd was not yet erupted.

The ovaries and the fetus were examined by Dr. Paul H. Baldwin, Department of Zoology, Colorado A. & M. College. After comparison with other reproductive tracts collected at the same time, he concluded that the pregnancy apparently was normal, and that the fetus (213 mm. in total length) was at the expected stage of development for that time of year.

Murie (1951. The elk of North America.) says: "Normally a cow elk breeds for the first time in the third rutting season after birth, an average age of about 2 years, 4 months. Although a large number of so-called yearling elk cows have been examined in winter for disease and indications of breeding, one with calf was never found, and only one published record of such occurrence has been noted." That instance was observed in the Yellowstone herd by Mills (1936. Observations on Yellowstone elk. Jour. Mamm., **17**(3): 250–253.), who found an elk cow "approaching 21 months of age" carrying a perfectly healthy, female fetus. He examined the ovaries of 2 other cows of the same age, found no scars or other signs of pregnancy, and concluded that they were not yet sexually mature. During the 1950, 1951 and 1952 reductions in Rocky Mountain National Park, a total of 6 other yearling cows were killed and examined but none of these was carrying a fetus.

Accepted for publication April 29, 1952.

"BONE BOARD" FOR BIG-GAME FIELD WORKERS

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Wildlife biologists, particularly those concerned with big game, often find it expedient to identify skeletal remains. On range holding two or three big-game species, in addition to domestic stock, positive field identification is often difficult, even for experienced workers. The accompanying comparison of selected bones of the cow, sheep, and 4 common big-game animals is designed to aid technicians, stockmen, and others in this respect.

In assemblying the "Bone Board" illustrated here, great care was given to the selection of uniform materials. Thus, only *mature, female* animals were used, and all bones, except vertebra, were taken, arbitrarily, from the *left* side. Display for each of the 6 bones was the same, mounting being in such manner as to permit maximum surface view. Cartilage caps were removed, leaving nothing except permanent bone structure. Special care was given to the preservation of structural processes at or near bone edges and extremities. Two vertebra, taken at the point of the shoulders, were displayed in such manner as to permit top and

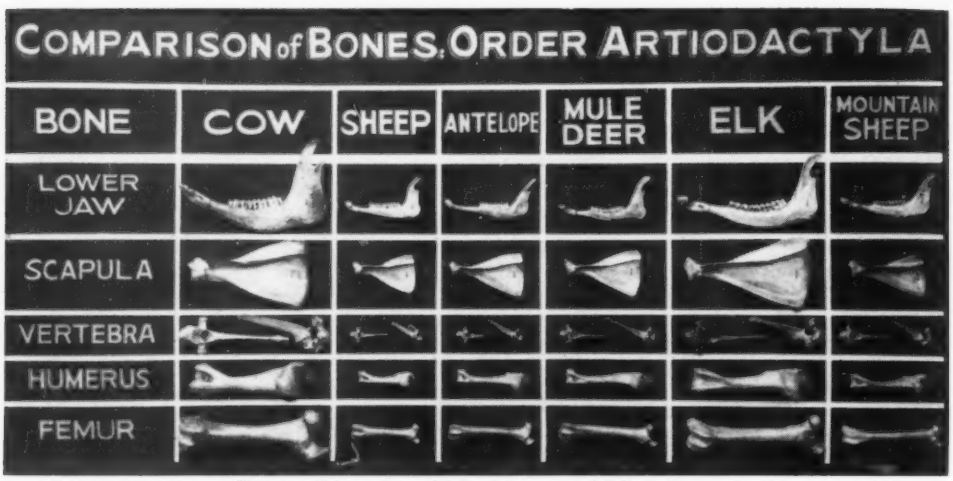

FIG. 1. "Bone board" for big game field workers.

bottom views of this complicated structure.

Mounting was on 7/8" fir plyboard, 4 x 8 feet in size. These dimensions serve as a scale. The plywood board was painted black; space lines, white. Bones were mounted with stovepipe wire, extended through holes and fastened on back of the board.

Big-game technicians of the Colorado Game and Fish Department, using an 8 x 10 inch photograph of the "Board" pictured, are able to identify, under field conditions, most skeletons of the 6 species shown. Exceptions include very old remains with key bones either missing, decayed, or badly gnawed; and juvenile animals lacking some of the diagnostic structures illustrated. Possibly male animals may offer some difficulty, since all materials in this assembly are from female animals. Limited comparison of jawbones, scapula, and leg bones from males has so far disclosed no special difficulty in identification. Ocular examination discloses the distinct difference in the jawbone, for example, in the various species, and suggests the feasibility of keys to supplement pictorial identification.

The foregoing is suggestive of further development in the interest of serving local, or more general, needs. Obviously, other species—white-tailed deer, moose, caribou, and mountain goat, and such domestic forms as goat and perhaps hog—could be added. The bones of any group—bears, the dog family, the cat family, weasels, etc.—could of course be compared. A series of 8 x 10 inch photos showing the comparative bone structure of domestic stock, important big game, fur animals, and upland game would provide biologists with useful tools for making skeletal identifications in the field. A half-dozen such group photos would meet all ordinary needs, and would take little space in a notebook. Where time and facilities permit, it is suggested that separate "Boards" be prepared for male, female, and juvenile animals, since numerous structural differences, especially in dentition, exist in the various age classes of the same species.

In field practice, the photograph is inserted in a notebook or attached to a clipboard, both to facilitate handling and to protect it from the weather.

Cost and time required for "Board" construction may surprise those who have not undertaken similar jobs. In the present instance, plyboard, paint and hardware cost about $12; student labor for cleaning and mounting bones, about $90. An elapsed period of about 16 months was required for assembling materials, and I had the assistance of the Colorado Game and Fish Department. The total cost of the display, excluding supervision and bone collection, was nearly $3 per bone. This cost, through more systematic efforts, can undoubtedly be reduced.

For assistance in collecting materials, I am indebted to Robert R. Elliott, Gordon Douglas, Jack R. Grieb, C. E. Till, Claude White, and

other Colorado Game and Fish Department personnel; and to Dr. R. W. Davis of the Department of Veterinary Anatomy, School of Veterinary Medicine, Colorado A. & M. College. Hal M. Boeker, Hal M. Swope, and Ervin L. Boeker aided in preparing bones and mounting them on the display board. William E. Carnahan, Colorado A. & M. College Photo Shop, made the photograph.

Accepted for publication May 16, 1952.

INITIAL PROOF OF MULE DEER FAWNS BREEDING IS FOUND IN UTAH

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and
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In September of 1951, Lloyd Stevens, eastern Utah Game Manager, observed what he believed to be an unusual oddity. He witnessed a fawn mule deer (*Odocoileus hemionus*) nursing a yearling doe at Price Game Farm in Carbon County, Utah.

The story behind this unusual circumstance began on July 4, 1946, when a sheep herder brought a doe fawn, estimated a few days old, to the Price Game Farm. She was given the name of "Babe" and was placed in a two-acre browse plot which consisted mainly of willow. The only supplemental feed supplied to "Babe" was mixed grain and salt, which was always available.

"Babe" was kept in this inclosure during the summer months, but was given her complete freedom during the breeding and winter seasons. She conceived the first time in 1947, and gave birth to a female fawn on July 2, 1948. On June 29, 1949, a buck fawn was born to "Babe". In 1950, her first set of twins arrived —a doe and a buck. The buck was castrated with the intention of keeping all three deer at the farm. However, the following year proved too productive for the limited available summer range. "Babe" gave birth to a buck fawn and the yearling, her female fawn of 1950, gave birth to a doe fawn. This doe fawn was not observed until September, and was estimated to be approximately two months old when seen. (Spots were still present but starting to fade.) The fawn was observed nursing the yearling doe on many occasions.

The yearling doe was observed with a distinct disorder of her hind quarter which did not exist prior to parturition.

The only other evidence indicating fawns breeding in Rocky Mountain mule deer was found by Robinette and Gashwiler, (Jour. Wildl. Mgt., Vol. **14**(4): 457–469, 1950) who found three legally killed yearling does from which the hunters had removed the udders. This evidence, together with acknowledgments by the hunters that these does had developed udders containing milk, was considered by these writers as circumstantial evidence that Rocky Mountain mule deer do occasionally produce young at the yearling age.

To make sure of this phenomenon, and also to alleviate over-use by the confined deer at Price, the yearling doe, her fawn, and also the 1951 buck fawn of "Babe's" were killed on January 28, 1952. (A note of interest might be that the castrated buck fawn of 1951 produced no evidence of antler growth the following summer.) The two reproductive tracts of the females and the skulls of all three deer were collected because of their known-age value.

Using Cheatum's method (Cornell Veterinarian **39**(3): 282–291) the ovaries of the yearling were sectioned. Two current corpora lutea were observed and one old scar was evident indicating pregnancy of the previous year. The udder was dark around the nipples, and the nipples were long, indicating a maternal udder.

The uterus itself was swollen with "uterine milk" present, but no embryo or visible membrane was observed.

The reproductive tract of the female fawn indicated no evidence of ovarian activity.

All evidence of this unusual happening is preserved at the Fish and Game Department office at Salt Lake City, Utah.

Accepted for publication March 17, 1952.

CONSTITUTION AND BY-LAWS
OF
THE WILDLIFE SOCIETY

CONSTITUTION

Article I—Name

The name of this Society shall be The Wildlife Society.

Article II—Objectives

The principal objectives of the Society shall be: (1) Establishment of professional solidarity and the maintenance of the highest possible professional standards; (2) development of all types of wildlife management along sound biological lines; (3) publications to effect these ends; and (4) protection of the interests of its members.

Article III—Membership

Section 1. The membership of this Society shall consist of Members, Life Members, and Honorary Members.

Section 2. Membership shall be open to all persons interested in wildlife management.

Section 3. Any person may become a Member upon the recommendation of two Members and acceptance of the Secretary.

Section 4. Honorary Members shall be persons who, upon a two-thirds vote of the Council and a two-thirds vote of the Members present at any stated annual meeting of the Society, are thus recognized for their distinguished service or outstanding achievement in the field of wildlife management.

Section 5. All classes of Members shall be entitled to vote, to hold office, to represent the Society officially when so appointed by the President or the Council, and to receive the Journal and such other publications of the Society as the Council may direct.

Section 6. The majority of those voting will determine the results of any election or other balloting.

Section 7. Any Member may become a Life Member by paying the sum of $100.00, either as a lump sum or not less than $25.00 per year over a period not to exceed four years. Such money will be deposited in the Permanent Trust Fund. Life Members shall be exempt from payment of annual dues.

Article IV—Officers

Section 1. The officers of the Society shall be a President, a Vice-President, a Secretary and a Treasurer.

Section 2. The officers shall be elected by mail ballot except as noted below. The President and the Vice-President shall serve until the end of the annual meeting of the calendar year following their election and shall be eligible to succeed themselves for a period not to exceed a total of three consecutive terms of one year each. The Secretary shall be elected to take office in each odd numbered year and shall serve until the end of the annual meeting in the next odd numbered year. The Treasurer shall be elected to take office in each even numbered year and shall serve until the end of the annual meeting in the next even numbered year. Before

June 1, the President shall appoint a Nominating Committee of five members. Before September 1 of that year the Nominating Committee shall submit to the Secretary two available Members as nominees for each office to be vacated. The Committee's nominations shall be published in the next October issue of the Journal of Wildlife Management or Wildlife Newsletter. Within 30 days of the date of mailing of this issue the names of additional available nominees for any office to be vacated may be submitted by any voting Member in good standing and any nomination will be valid if supported by 5 per cent of the voting membership. The Secretary shall then mail to all members an election ballot bearing the Committee's nominations and those made by the membership as herein provided. Thirty days shall be allowed for the election ballots to be returned to the Secretary. The nominee receiving the largest vote for each office shall be declared elected. In case of a tie, the decision shall be made by a majority of the Council. The outgoing President shall appoint a three-member committee within thirty days after the election to audit the nomination and election ballots. The auditors' report on balloting shall be published in the Journal of Wildlife Management or Wildlife Newsletter.

Section 3. The President shall preside at meetings of the Society, shall be Chairman of the Council, shall appoint all Committees, including those established by the Council, and perform other duties incident to his office.

Section 4. In the absence of the President or in his inability to act, his duties shall be assumed by the Vice-President. In the event neither can serve, the Council shall appoint a President pro-tempore.

Section 5. The Secretary shall be the Executive Officer of the Society under the general direction of the Council. He shall issue notices of annual or special meetings of the Society. A report covering his activities during the preceding year shall be made by him to the Society at its annual meeting.

Section 6. The Treasurer shall be responsible for all funds of the Society except Permanent Funds held in trust and shall be bonded in suitable amounts as decided by the Council and at the Society's expense. His accounts shall be audited at the close of each fiscal year as directed by the President before presentation at the annual meeting of the Society.

Section 7. Vacancies among the officers shall be filled by vote of the Council from among the Members for the unexpired term of the office or until the next regular election.

Section 8. The Council, by a two-thirds vote, may combine the offices of the Secretary and Treasurer into one office entitled the Executive Secretary. The Executive Secretary shall be appointed by a two-thirds vote of the Council. The Council may pay him a salary and expenses at its discretion and within sound financial limits of the Society. The Executive Secretary shall carry out the duties and make reports as specified in Sections 5 and 6 of this Article. The combining of the offices of Secretary and Treasurer shall take place at the end of the annual meeting, of same year, and a notice of such union shall be made to the membership at least six months prior to the change. The Council, by a two-thirds vote, may

eliminate the office of Executive Secretary, if conditions warrant, and restore the separate offices of Secretary and Treasurer, and have these offices filled according to Section 2 of this Article. A petition, having at least 10 per cent of the signatures of Members will be sufficient to require the Council to submit to the voting membership for approval or disapproval of appointment or discharge of an Executive Secretary.

ARTICLE V—COUNCIL

Section 1. The Society shall be governed by a Council, composed of the President, Vice-President, Secretary, Treasurer, out-going President, and at least one representative from each of the Regions as defined in the By-Laws. The Regional Representatives shall be elected annually, shall be eligible for re-election, and shall take office at the end of the annual meeting following their election.

Section 2. The Council shall appoint the Editor; shall have power to fill vacancies occurring in its numbers; shall recommend to the Society for action, By-Laws not inconsistent with this Constitution and shall perform such other duties as are herein prescribed. Not less than one-half of the Members of the Council shall constitute a quorum. In case a Council member is unable to attend, he is authorized to appoint a qualified member as an alternate as his official representative on the Council providing he has so notified the President prior to the meeting.

Section 3. If the offices of Secretary and Treasurer are combined into an office of one person, entitled Executive Secretary, an appointee, the Executive Secretary shall not vote on Council affairs.

ARTICLE VI—MEETINGS

Section 1. Unless the Council directs otherwise, the Society shall hold an annual meeting. The Council may direct that other meetings be held at places and dates selected by them. Due notice of such meetings shall be given by the Secretary at least thirty days in advance.

Section 2. Resolutions proposed for consideration at any meeting of the Society must first receive approval of the majority of the Council, and if subsequently approved by the majority of the members attending the Society meeting, such resolutions shall represent the official view or recommendations of the Society.

ARTICLE VII—SECTIONS

Sections of the Society may be authorized by the Council upon petition of ten or more Members. Sections may adopt necessary By-Laws, providing that no part of them shall conflict with the Constitution of this Society. A report of its activities shall be presented by each section at the annual meeting of the Society.

ARTICLE VIII—DUES AND FUNDS

Section 1. The annual Membership dues shall be $5.00. Subscriptions shall be $5.00 beginning with Volume 12. No dues shall be charged Honorary Members.

Section 2. Annual dues shall be payable from January 1 in advance. Members in arrears shall forfeit their rights and privileges and shall receive no publications until such dues are paid.

Section 3. All monies accruing to the Society received for undesignated purposes shall constitute the Permanent Trust Fund, the proceeds from which shall be utilized to carry forward the work of the Society as directed by a three-fourths vote of the Council. In the absence of such direction, this income shall be reinvested by the Trustees.

Section 4. Bequests, grants or trusts made for the purpose of advancing the field of wildlife management and/or The Wildlife Society may be accepted by the Society, providing the Council shall have first favorably considered the objects and specifications set up by the trust. These shall be placed in the Permanent Trust Fund.

Section 5. The Permanent Trust Fund of the Society shall be controlled in trust by a board of three Trustees with power to sell and reinvest according to their judgment. One Trustee shall be elected at each annual stated meeting for a term of three years. In case of vacancies caused by suspension, resignation or death, successors shall be appointed by the Council for the remainder of the term. The Trustees shall be bonded in suitable amounts as directed by the Council and at the Society's expense.

ARTICLE IX—AMENDMENTS

The Constitution may be amended by a two-thirds vote of the Society Members who return ballots in response to a notice of the proposed amendment. Such notice must be submitted to all Members at least thirty days previous to the closing date for the receipt of ballots. Amendments may be referred to the Society for action either by a two-thirds vote of the Members at any stated annual meeting, or by a favorable vote of at least two-thirds of the Council.

BY-LAWS

I. ELECTION OF OFFICERS

Election of officers shall be made by mail ballot as specified by the Constitution.

II. ELECTION OF COUNCIL

Representatives to the Council shall be chosen, one from each region, as follows: The Regional Representative for each Region shall be nominated and elected annually by mail ballot by Members residing in each Region. Nomination ballots shall be mailed to all Members by the Secretary by August 1, each year. Each Member may nominate three qualified persons residing in his region as his first, second, and third choices for representative from that Region. Thirty days will be permitted for Members to return their ballots. After the 30-day time interval, the Secretary will tabulate the results. The Members' first choice will receive 3 points; second choice, 2 points; and third choice, 1 point. The two nominees receiving the most votes within each Region shall be listed on the annual election ballot for Society officers. The nominee for Regional Representative who also is nominated as an officer shall be placed on the ballot only for the officer position and the nominee for regional representative holding the next largest number of votes shall be substituted for him on the bal-

lot. Regional Representatives shall be eligible for reelection and shall take office at the end of the annual meeting following their election. The Regions shall be as follows:

Region 1: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Maryland, Delaware, District of Columbia, and West Virginia.

Region 2: Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, Puerto Rico, and Virgin Islands.

Region 3: Ohio, Michigan, Wisconsin, Minnesota, Iowa, Missouri, Illinois, and Indiana.

Region 4: North Dakota, South Dakota, Montana, Wyoming, Nebraska, Colorado, and Kansas.

Region 5: Arizona, New Mexico, Texas, Oklahoma, and Mexico.

Region 6: Washington, Oregon, California, Idaho, Nevada, Utah, Alaska, and Hawaii.

Region 7: Canada.

Additional Regions may be established for similar representation upon approval by the Council.

III. Order of Business

The order of business at the annual stated meeting, unless changed by a two-thirds vote of the Members present, shall be as follows:

1. Reading and approval of the minutes of the previous meeting.
2. Report of the Secretary.
3. Report of the Treasurer.
4. Report of the Regional Representatives.
5. Appointment of temporary committees.
6. Report and recommendations by the Council.
7. Action on business reported by the Council.
8. Report of Committees.
9. New and Unfinished business.

IV. Delinquents

A Member shall be dropped from the annual list of Members after becoming one year in arrears of dues. A Member shall be reinstated upon payment of dues for the current year in which application is made. Any Member serving in the Armed Forces may obtain back numbers of the Journal of Wildlife Management for the time he was in arrears because of the war at regular prices. All other delinquents shall pay current prices for back numbers. This provision shall be in force until such time as the military crisis ends in Korea.

V. Fiscal Year

The fiscal year of the Society shall end the last day of February.

VI. Editor

The Editor shall be appointed by the Council. He shall serve one year, or until his successor is appointed, and shall be responsible for all matters relating to the publications of the Society, subject to such restrictions as may be imposed by the Council.

VII. By-Laws

By-Laws may be adopted, amended, or repealed at any annual meeting by a majority vote of the Members present.

REVIEWS

Resource Conservation: Economics and Policies, by S. V. Ciriacy-Wantrup, University of California Press. 1952. 395 pp. $6.50.

The title and the publisher's announced table of contents call conservationists' attention to this book. Potential readers should be warned that unless they have some familiarity with economics they may find themselves morassed in economic theory and terminology, in portions of the work at least. On the other hand, one of the important things about the book is that it attempts to bring conservation to the economist on his own terms. An agricultural economist at the University of California, Ciriacy-Wantrup accepts the conservation movement without quibbling and launches forth to interpret it.

The author considers the concept "resource" to be meaningful only in relation to "a planning agent," as an individual, corporation, or community that considers use of the environment to obtain certain needs. "A resource, therefore, is a highly relative concept changing with the ends-means scheme—that is, with the planning agent, with his objective, with the state of technology, and with existing social institutions." "Resources," the author continues, "are variables in a socially most significant function in which man, objectives, his knowledge, and his institutions are other variables." The ecologist must admit the value of this dynamic approach.

Using the economists' accepted differentiation, resources are divided into two categories: "stock," in which quantity does not increase with time, and "flow," in which quantities are successively available. The difficulty of arbitrary groupings is illustrated when the author admits that soil is a composite of many interrelated stock and flow resources and that hydroelectric power is a resource that does not fit readily into either group. His classification follows:

I. Nonrenewable or stock resources.
   1. Stock not significantly affected by natural deterioration. Examples: metal ores *in situ;* coal; stones; clays.
   2. Stock significantly affected by natural deterioration. Examples: refined metals subject to oxidation; oil and gas in cases of seepage and blowoff; plant nutrients subject to leaching; radioactive substances (radium, uranium, plutonium, etc.) in process of nuclear disintegration.

II. Renewable or flow resources.
   1. Flow not significantly affected by human action. Examples: solar and other cosmic radiation; tides; winds.
   2. Flow significantly affected by human action.
      (a) Reversibility of a decrease in flow not characterized by a critical zone. Examples: precipitation, special locations that form the basis of site value; services from a species of durable producer and consumer goods.
      (b) Reversibility of a decrease in flow characterized by a critical zone. Examples: animals and plants; scenic resources.

The critical zone is that below which a decrease in flow is economically irreversible. With an animal species flow is stated to be technologically irreversible with extinction—when flow reaches zero.

Ciriacy-Wantrup makes much of the point that the meaning of conservation is interpreted correctly only when considered in terms of time. "Conservation is concerned with the *when* of use. . . . In conservation, the redistribution of use is in the direction of the future; in depletion, in the direction of the present." The optimum state of conservation is said to be "an economically optimum distribution of rates of use over time."

The above notes are from Part I, Orientation of the Study. Parts II and III deal with the private economics of conservation. Interest, uncertainty, price, property, tenancy, credit, taxation, and other economic factors affecting individuals are considered in relation to conservation.

Parts IV and V deal with the social economics of conservation. Conservation policy is defined "as that state of conservation which maximizes social net revenues over time." To avoid the critical zone, a safe minimum standard of conservation is called for—a social objective actually realized as a kind of economic base level. Domestic tools of conservation policy

(education, zoning, regulation) as well as international tools (conferences, treaties, and agreements) are discussed.

Because "world distribution of stock resources in an industrial age decisively influences the political ambitions and fears of nations," Ciriacy-Wantrup calls for a Mineral Resources Organization of the United Nations, to parallel the Food and Agriculture Organization which deals with flow resources. In the final chapter the author treats coordination of conservation policy, and calls for reorganization of government agencies—state and federal—into two departments: "Agriculture" to deal with all flow resources (except hydroelectric power), and "Mineral Resources and Power" to deal with stock resources and power. He discusses in some detail the implementation of this suggestion.

There is an index, and a three-page appendix giving an abstruse mathematical definition of conservation. The book is attractively printed. There are no illustrations, and one misses a preface and summary statement. The biological and physical scientists who have been concerned with care and use of natural resources may find encouragement in this book, for in it a social scientist gives serious attention to the relationship of economic and social forces to natural resources.—EDWARD H. GRAHAM.

Conservation in Canada. By O. M. McConkey. J. M. Dent & Sons, Toronto, Canada. xix+215 pp. illus. 1952. $3.50.

This small volume should prove valuable in encouraging the teaching of conservation in Canada. It is written simply and clearly, is profusely illustrated, and assumes no "prerequisite" training in the various aspects of natural resources which it considers. It should be helpful to teachers in both elementary and secondary schools who have not usually had the advantage of specialized training in conservation, and it seems to me so simply presented that students in the secondary schools would find it interesting collateral reading.

Where many texts in the conservation field tend to be heavily factual and statistical, this little book seems to me very effective in expressing a conservation philosophy which should enhance its value to the public school teacher.

The author is Professor of Field Husbandry at Ontario Agricultural College at Guelph, which is reflected in the proportion of space devoted to matters of soil and water conservation as related directly to agriculture, but there are a few pages on forests, wildlife, recreation, and minerals and oil.

Public school teachers in the northern states, where the conservation problems are so similar to those in Canada, will find the volume well worth acquiring.—G. A. SWANSON.

EDITOR'S CONCLUDING NOTE

This completes my stint of four years as Editor of the JOURNAL. In passing on the responsibility to Dr. Hewitt, I want to express my sincere thanks to the many who have been so helpful. Authors and readers alike have generally been so appreciative, and so patient and sympathetic with editorial frailties that the responsibility has been a pleasant one. Many members of the Society have willingly reviewed manuscripts and books in their fields of specialization. The four successive Councils have always been very cooperative. And particular credit is due the Associate Editors. Dr. Carlander relieved me of most of the editorial burden for fisheries papers, and Dr. Hewitt has shared most generously in all editorial responsibilities, from initial review of papers to page-proof reading. To all who have contributed so willingly, my sincere thanks, and the hope that you will give Dr. Hewitt the same helpful cooperation.

GUSTAV A. SWANSON